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THE PROGRESS OF CHEMURGY

by

WHEELER McMILLEN

President of the National Farm Chemurgic Council, Inc.; Editor-in-Chief of the Farm Journal; Editorial Director of the Pathfinder

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To

JOHN W. TICKNOR

and

ERNEST L. LITTLE

"To my mind, the most significant of all encouraging signs is the phenomenal growth of this farm chemurgic movement which is sweeping the country despite opposition from those who misunderstand it or who believe that their personal interests will be served by its failure. But it will not fail, because it is pointed right in the direction of progress; it is based on the new philosophy of creating wealth and opportunity for all rather than the age-old instinct of taking wealth from others; it is essentially cooperative between agriculture, industry and the general public, rather than competitive between them."

—Dr. Karl T. Compton, President of the Massachusetts Institute of Technology, in an address at the Third Chemurgic Conference in Detroit, May 25, 1937.

Preface

PROBABLY about nine out of ten people in the world live and die in poverty. A fair guess is that not more than two hundred million people, one-tenth of the two billion human beings currently in the world, enjoy a standard of living comparable to that of the average American.

This is not for lack of natural resources, but because of ignorance of them.

Plants grow nearly everywhere in every land. Unlike irreplaceable minerals, their abundance is ever-renewable. The crop grown and used in one year can be repeated and even increased in the next. Man need never fear poverty if he sufficiently understands and utilizes the wealth of the vegetable kingdom.

Chemurgy may be accurately defined as a concept devoted to advancing, through applied science, the development of new industrial uses for farm-grown materials, and the establishment of new farm crops.

If that sounds like a narrow base on which to rest a philosophy of universal human importance, let it be remembered that all wealth derives from the soil, the seas and the mines. By far the larger and most essential part comes from the soil. Truly complete realization of the potential wealth in plant resources could make the whole human race rich as compared with present standards. And if the whole human race were not rich, but even comfortably out of want, the hope of a peaceful world certainly would be far more realistic.

Chemurgy, like science, knows no boundaries. However, if one prefers to measure the concept within America only, he still finds that new uses for farm-grown materials and new crops profoundly influence not only farmers, but Fifth Avenue and Capitol Hill, and the whole social and financial status of the nation.

Nearly half of the nation's population—the farmers and all those who buy and sell and serve in rural areas—depend for their prosperity wholly upon the new wealth and the new dollars which farmers bring to town. The other urban half is certain of prosperity when the rural half has spending money with which to buy the goods and services of the cities. The flow of rural spending money can best be assured by establishing new crops that pay better than some of the old "surplus" makers, and by finding new uses that stabilize the demand for agriculture's output. Chemurgy offers means toward the prevention and cure of the surplus problem, means that are not legislative but economic and scientific.

An effort is made here to report, in a series of loosely organized narratives, the major and most interesting achievements in the various fields of chemurgy. The emphasis throughout has been upon those achievements which have been substantiated by commercial success. Countless other projects are in laboratory or promotion stages and many are exceedingly intriguing. It was thought preferable, however, to tell of the things that have been accomplished, rather than of those that may yet be realized. Even so, occasional potentialities too interesting to be ignored are included, either because they may soon become important or because they illustrate a point.

Readers will soon discover that the book attempts what may be regarded as three somewhat separate purposes: (1) to report practical chemurgic developments, (2) to set down the history of the chemurgic concept and of its organization and (3) to set out fully the significance and implications of the underlying philosophy.

The author of this book is not a scientist. He is an agricultural editor and reporter and perhaps a sort of evangelist. Twenty years ago he became convinced that mere law-passing could never assure a stable and prosperous American agriculture. Since then he has sought to make available, to all who wanted to know and think about them, the ideas developed in these pages.

The author is indebted to so many friends in so many fields of knowledge for information, for checking chapters and parts of chapters, that in acknowledging their numerous individual contributions he can hardly make any other effort than to say thanks to all of them for helping complete this book, the essential message of which is: wherever plants grow, man's frontiers are limitless.

WHEELER McMILLEN

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Part One

CHAPTER I

The Background

I

THOSE who are searching hopefully for a major panacea to remedy the ills of the world will not be wholly satisfied by what they find in this book. Nevertheless they will find a prescription which, if sedulously applied, will effect more complete cures for economic and social ailments than the remedies applied so far by the statesmen.

Those who are concerned with means to accomplish such lesser purposes as the increase of employment in the United States and the stabilization, to some degree, of the nation's economy, will find a basic idea that may challenge their imaginations. Those who search for routes to a sound and prosperous agriculture will, I can promise, discover rather extensive areas of interest.

Since economic snake oils have never been so scarce as to need to be rationed, and since the meaning of the term chemurgy is not yet universally familiar, these broad assurances, qualified though they are, may seem entirely too sweeping to be credible. Without pausing to debate over that reaction, the immediate essential is a brief definition of chemurgy and some account of what it is all about.

This book is mainly a series of narratives, each with a fairly definite point of beginning and some sort of a climax. Each ending is punctuated with a period only because what will be brought about tomorrow is not available to be printed today. All the stories are unfinished. Along with these narratives of accomplishments there is told also the story of the underlying idea for which the events described are witnesses, the story of how the idea began and unfolded, and of how it has logically expanded far beyond the original concept; and briefly, too, the story of the organization which grew up to promote the idea.

The narratives will be much more stimulating to the reader who will pause first for a prelude wherein the stage is partially set and the nature of the entertainment foreshadowed.

II

Chemurgy is exclusively concerned with the vegetable kingdom, and not with the mineral world. The reason for this is highly important, yet relatively simple. Nevertheless unless one has an exceptional gift of comprehension he is likely to require some time to grasp the full extent of its potentials. Those most intimately associated with the chemurgic concept will freely confess that such has been their own experience.

The vegetable kingdom reproduces itself. The mineral kingdom does not.

So far as anyone can know, the forces of nature are not creating more iron or tin or petroleum, or any other of the minerals which man uses. When a ton of iron ore is scooped out of the crust of the earth, another ton is not put back in its place. When a barrel of petroleum is pumped to the surface, there is one less barrel in the underground reserves. When the mineral material is used it has disappeared forever from its original form, unless there happens to be some salvage value. The industry or economy which is dependent upon the mineral world operates with a species of raw material which not only is exhaustible but which also is irreplaceable.

Quite the opposite is true in the plant world. Most of the valuable plants of the earth are annuals; that is, they are sown, grown and mature within the period of a single year. Others are biennial, requiring a two-year space of time to achieve maturity. A few are perennial, like the alfalfa crop which, once planted, yields frequent harvests over a period of several years. Among the fruit and nut trees from four to ten years may elapse before a crop is borne; thereafter an annual harvest may be expected for the life of the tree. The longest plant cycle is in the forest, where from ten to fifty or more years must pass before a tree can be harvested for timber.

But whether the member of the vegetable kingdom is an annual, a biennial, perennial, or a slow-growing tree, there is still the outstanding fact that it is reproducible. Even the giant redwoods and sequoias are replaceable if man waits long enough.

Consequently those industries which look to agriculture and forestry for their raw materials have a constantly-renewable source of supplies. If they consume annual crops, no matter what their volume of this year may be, the coming of next year's spring will start the replacement of the entire amount, and so on year after year into the future. If they consume a product with a longer cycle, the only difference is that it takes a little longer. No one need ever say: "That's all; there isn't any more."

Of course, the weight of this consideration could be exaggerated. Mineral resources are not going to be exhausted right away. War's destructive use has certainly spent enormously of our mineral treasure and has caused it to be exported, burned and sunk beyond all hope of recovery. Even so, doubtless more iron is in the earth than has ever been taken out, and more of many other metals. Aluminum, in the form of clay, is one of the commonest of all minerals. Even petroleum, the imminent exhaustion of which has been predicted long years since, has so far confounded the oil pessimists, as new fields have been discovered from time to time.

Nevertheless the fundamental fact is irrefutable—mineral resources are not replaceable, while plant resources are regularly and fully renewable. Moreover, the plant resources can be renewed in almost any quantity that human requirements may demand. If there is need for less copper and more iron, the mining industry cannot turn the copper mines to the production of iron. On the other hand, if twice as much corn is demanded and less wheat or soybeans, some of the wheat and soybean fields can be put to producing corn.

It is also generally true that as mineral resources are depleted the cost of their extraction and transportation tends to become greater. The petroleum industry has had to drive deeper wells at greater expense. The richest metal deposits become worked out and greater effort has to be expended to obtain the product from lower grade ores or from mines located more remotely from the centers where the metals are desired.

In contrast, greater demand for a crop of raw material inspires modern agriculture to improve the seed, the cultural methods and the soil treatments, so that the actual cost of production tends to become lower as more of the product is needed.

One other observation is appropriate on this theme. When a community or region builds up a local civilization around agriculture, a considerable degree of social and economic permanence ensues. That usually is a stable area where society can expect for some centuries to see churches, schools and homes. If one crop is no longer profitable, the good soil will produce another equally well or better, and the social continuity goes on unbroken. The only qualification is that the community does take care to see that the soil itself does not become exhausted or eroded away. Agricultural communities a thousand years old can be found around the world. Extractive mineral industries leave ghost towns behind them; sound agriculture does not.

III

Out of what is a plant made? What difference does it make, some may ask, that an entire new supply of plant materials can be reproduced with each season of growth? Plants grow out of the soil, and the soil is made of minerals; is not agriculture, too, an extractive industry in the sense of taking those minerals out of the soil to make plant structure, eventually exhausting those minerals? Haven't we even heard of soilless culture, a method where plants are grown in sterile sand through which they are supplied with nutrient solutions of the necessary minerals dissolved in water?

The answer is that the soil minerals, while vital to plant growth, contribute very little to the actual content of the vegetable material. On the average ninety-eight per cent of the material in the plant, in the roots, stem, leaves and seed, is not the product of the soil minerals, but the product of atmosphere and moisture; air and rain, in other words, are transformed by the mysterious power of sunshine into the solid substance of the plant. About ninety-eight per cent of that substance is air and rain, whether the plant is a juicy watermelon or a solid oak tree.

The minerals actually extracted from the soil contribute the other two per cent, or approximately the portion of the plant substance left in ashes after burning. In a few species the mineral content may run as high as five per cent. The elements principally required are phosphorus, potash and nitrogen, along with minute traces of ten or a dozen others, such as copper, zinc, cobalt, boron, all usually present in sufficient quantities.

Phosphorus, potash and nitrogen are the three elements most generally purchased in fertilizers. Estimates indicate that the United States has enough phosphorus resources, if they are not recklessly used, to replenish the deficiencies in cultivated soils for many decades to come. We have a moderately adequate known supply of potash, and there are large quantities elsewhere in the world. Nitrogen is no longer a limiting factor, since abundant quantities can be extracted from the atmosphere at a cost low enough to permit its use in fertilizers.

Although not particularly pertinent to this point of the discussion, extremely pertinent to the whole topic of soils and plant growth is the fact that the soil is by no means merely a mineral or chemical structure. Scientists are only now beginning to place greater emphasis on the biological factors in soil quality. Earthworms, multitudes of bacteria, and perhaps other forms of life, are without question essential to the maintenance of a healthy soil in which organic matter, acting upon and reacting from the mineral characteristics, contributes towards creating the combination of factors, known and unknown, which join to produce a plant structure replete with the ingredients ideal for human use.

The emphatic fact at this point is that atmosphere and moisture are the principal raw materials out of which farmers produce crops. Obviously, the supply of air is without any conceivable limit. There is plenty of air. While water is not always abundant in the exact place and at the precise time when the crops most need moisture, the total supply of water is ample. The rains and dews and snows will continue to fall as long as man has any interest in occupying the earth.

All this piles up to the monumental consideration that not only are man's plant resources constantly renewable and reproducible, but the primary materials out of which they are constituted are themselves the most abundant substances within the reach of man—the air and the water.

Consequently, so far as goods can be manufactured out of farm-grown materials, out of the vegetable kingdom, absolutely no limit can be set upon the production of new wealth, except the limits of man's own ignorance of the forces and materials with which he works. The more man learns about utilizing the wealth which grows out of the soil, the richer the world can be. This portends exactly as much for the future of the human race as the human race makes out of it.

IV

Farm (usually the word farm is omitted) chemurgy means putting chemistry and the allied sciences to work toward the greater industrial utilization of farm-grown materials. Conceived originally as an approach looking principally to the benefit of agriculture, the significance of the chemurgic idea has grown to national and international proportions, and has come to look far beyond the potential of agricultural good, great as that may be.

Chemurgy is not much concerned with food. It has to do almost wholly with the non-food utilization of farm-grown materials. Food and fiber for sustenance, clothing and shelter are the traditional business of farmers. While the world has never had enough of any of these fundamental necessities, agriculture has experienced many periods when profitable markets for food and fiber were not to be found. Chemurgy had its conception in one of those periods when it appeared that if effective purchasing power for food did not exist, the development of non-food demands might offer new markets for the products of the soil and, further, might help to create additional purchasing power for food and clothing.

No doubt for generations to come, and perhaps for always, the production of food will be the first duty of the land. However, people do not eat straw and cornstalks, nor many of the other chemical compounds, forms of cellulose, proteins, oils, starches and sugars which farmers produce. In order to put a pound of food on the market a farmer must usually grow another pound of material which no one can or will eat. About half the total tonnage of the agricultural output has been, in traditional practices, a tonnage of unmarketable wastes. Some of the chemical compounds grown on the land have higher values for purposes other than for food.

The primary activities which come under the heading of chemurgy, then, are these three:

1. Development of new, non-food uses for established farm crops.
2. Establishment of new crops for new or old uses.
3. Discovery of profitable uses for agricultural wastes and residues.

V

A question naturally arises at about this point in the discussion of chemurgy. Agriculture is an ancient pursuit. Why hasn't chemurgy been considered long before? Why does it come into sight at this particular time?

The answer is that the tools for chemurgic performance have just recently come into view. Men have grown crops for centuries in order to eat the grain of the wheat and corn, the pulp of the apple, and to wear the fiber of the cotton, because no means existed for other forms of utilization. Foodstuffs had to be eaten raw or after simple mechanical preparation and cooking. Fibers could be used only if they were produced by nature in a reasonably convenient form for spinning, weaving or felting.

The three great new tools now available to agriculture, which make possible much greater enlargement of human wealth than ever in the past, are so new that even yet relatively little about their application has been realized.

The first of these is the science of organic chemistry.

The second is the science of plant genetics.

The third, which perhaps should be first, is the art of the engineer.

The engineer has devised power and equipment by which man can collect, lift, move, grind, shape and process materials. His engines and machines do work which human muscles were never able to undertake. They do work at costs far below the costs of human and animal power. This economic angle is of foremost importance, for unless work can be made to pay it will not be undertaken.

The engineer's role in chemurgy may be illustrated by the problem of utilizing cornstalks. Cornstalks are light, bulky, and widely scattered. If men had first to cut and husk the corn by hand, tie the stalks in bundles, pitch them by hand on to wagons, and haul them with horses, and if the hand-tied bundles had then to be transported by freight cars from a country shipping point to a factory, the cost of the cellulose fibers in the cornstalks would be prohibitive for any industrial use now known. Other materials would be so much cheaper that the cornstalk would have no chance to be considered. The engineer's devices for chopping and baling the cornstalks into moderately compact bundles have made it possible to load one freight car heavily enough so that one small factory has utilized them for several years. Cornstalks from a limited area were collected and manufactured into wallboard. The manufacturing problems involved are not too difficult. However, not until further engineering advances are made, and not until cornstalks can be assembled in large quantities at a still lower cost, will they become an important industrial material.

While an engineering problem not yet fully solved delays the cornstalk's chemurgic triumph, it was an engineering success that lifted the soybean to agricultural and industrial eminence. Numbers of farmers knew how to raise soybeans long before the crop became conspicuous. Planting and cultivation were fairly simple operations. Harvesting was difficult and expensive. The beans were usually cut by the grain binder and threshed by the threshing machine. Neither the binder nor the threshing machine did very good jobs with the beans. The whole method was cumbersome and expensive. Then agricultural engineers came on the scene with the combine-harvester which had been developed primarily for the wheat fields. This machine, with simple adaptations, cut and threshed the soybeans with a single once-over operation that proved to be cheap and efficient. With the harvesting hurdle overcome, farmers did not hesitate to multiply their soybean acres when the commercial demand for the new crop offered a constant cash incentive.

Without the tractor, without the new types of farm equipment which only a tractor has power to operate, and without electric power on farms, a great deal of the present and future industrial utilization of farm crops would not be feasible. And, of course, without the engineering advances in transportation and manufacture, industry would not be in a position to operate the necessary processes.

The agricultural engineer is an indispensable factor in chemurgic expansion. Although for more than a century, since the invention of the reaper in 1831 and of the steel plow about 1838, improvements in farm machinery, buildings, fences, drainage and irrigation methods have steadily appeared, the limited muscle-power of horses and humans bore the burden of work. Not until after the first World War did the tractor's snort really begin to replace the horse's whinny. Tractors on farms in 1920 numbered about 250,000. By 1945 the count had climbed to two million and the machines were infinitely more versatile and better adapted to farm work. Electric power was available to extremely few farms twenty-five years ago; now the still mysterious force produces light and energy and is doing chores—chores that once were laborious and time consuming muscle work on nearly three million farms.

The agricultural engineers have not only lightened and speeded the labor of transforming air and rain and sunshine into materials for human use, but they have lowered costs of doing the work so that many more materials are available at economic cost levels. Engineering has, in effect, introduced farm raw materials to the industrial chemist.

VI

The function of the plant breeder is to induce nature to suit her objectives to the purposes of man. Plants are not always well-adapted to the requirements imposed by economic demands. Nevertheless they may be nearly enough suitable that the competent geneticist, skilled in obedience to natural law, can take advantage of nature's prodigality and persuade her to produce a plant which in characteristics or contents will conform consistently to an economic need.

It is enough to say here, in advance of the more detailed account of his achievements in other chapters, that the plant breeder is able to take a plant which is only moderately suited to the purposes industrialists or farmers may have in mind and produce a strain which year after year, if kept pure, will yield uniformly the desired shape and content. The geneticist's achievement may be attained simply by discovering, selecting and reproducing a strain with the desired characteristics, or it may be accomplished by complicated breeding operations conducted in accordance with a natural law which was not understood until the end of the nineteenth century.

Corn, cotton, soybeans and grain sorghums are among the plants which, responding to the plant breeder's art, have adapted themselves to specific industrial uses. So new is the art that countless plants which may have chemurgic values have not yet had time to receive genetic attention. Like the agricultural engineer, the geneticist is a new expert on the land. Their two arts, when associated with the science of the organic chemist, join to open up the entire new vista of wealth and well-being towards which chemurgy is reaching.

VII

A plant in the process of growing from seed to maturity, while picking out of the air and moisture and soil the elements which its growth transforms, becomes eventually a specific arrangement of atoms and molecules. The arrangement of the fiber in a boll of cotton is an extraordinary assortment of molecules so attached one to another as to constitute cellulose in as pure a form as nature creates that useful product. The fibers are attached to a seed, and the content of the seed is about nineteen per cent vegetable fat, or oil.

If cottonseed oil is subjected to a certain degree of temperature under a specific amount of pressure, and if this is done in the presence of nickel dust, an atom of hydrogen attaches itself to each of the molecules of which the oil itself is composed. The oil then ceases to be a liquid at normal temperatures, and becomes a hard fat. Cottonseed oil, by this process, found a tremendous new market. American housewives as a rule do not like to cook with oil. They were long accustomed to using lard or butter. When they were shown that the hydrogenated cottonseed oil, used as a cooking fat, became rancid less easily than lard and was not so likely to pop hot particles out on their bare arms, millions of them abandoned the animal fats and adopted Crisco, Spry, or one of the other commercial vegetable fats.

This is a simplified illustration of the tremendously dramatic science of the organic chemist. His business is the rearrangement of atoms, the building of molecules, and the understanding of these structural materials. Through his knowledge of several of nature's formerly unknown and still largely invisible details, he can turn to human uses materials which were never before usable for the new purposes, and often to purposes which never before existed. He is ceaselessly competing with himself, as witness the fact that other organic chemists have found means to improve the lard, which cottonseed oil largely displaced, so that it can be marketed without the old tendency toward becoming rancid, and without the old popping grease characteristic.

The organic chemist, it might be said, is the fellow who can start with the bag of beans which the housewife would bake or boil, and by subjecting them to tremendous temperatures and terrific pressures in the presence of his mysterious catalysts cause them to emerge as an automobile door instead of as a bowl of soup. An organic chemist once made a silk purse out of sows' ears. You can see the purse on exhibition at the laboratory of Arthur D. Little, Inc., in Cambridge, Mass.

The organic chemist is always in search of materials which, with the least possible trouble and expense, he can transform into commercial products. The trouble and expense involved in making the silk purse from sows' ears was rather considerable. A more practicable method was devised when the long molecules known as polymers were studied and means were discovered to rearrange them on a commercial scale from air, water, lime and coal into the product known as nylon.

Nature, by her remarkably various achievements in plant life, has done a huge amount of the preliminary work for the organic chemist. When the chemist desires cellulose, he finds that nature, in growing cotton, wood and some other fibers, has gathered together large quantities of cellulose in forms with which he can work. The cottonseed, the soybean, and many other plants provide him with oils. Corn, potatoes, sweet potatoes, in the natural course of a season's growth, collect starch for him. Cane and beets make sugar. Large numbers of plants yield proteins from which the chemist can fashion items that appear so remote from the original soybeans or grasses that the transformation is truly fantastic; yet it works, it pays, it makes jobs, and contributes new things to the standard of living.

Like the plant breeder and the agricultural engineer, the organic chemist is new on the human scene. His science is little more than half a century old. Until it grew, chemurgy could not have been developed.

Other sciences, too, play important parts in chemurgy. The bacteriologist's knowledge of the microscopic creatures which cause fermentation is indispensable to the manufacture of industrial alcohols in the modern manner. The mycologist, who is master of molds and fungi, is just emerging into dramatic importance because of his contributions to penicillin and streptomycin, which may be only the first of a number of new industries.

CHAPTER II

How Chemurgy Started

I

THE seeds of the depression of the nineteen-thirties were planted in the war years 1914-18. They sprouted in August, 1921. That was when country banks were ordered by the Federal Reserve Board not to renew their notes from ranchmen and farmers but to collect them, in full and at once. Farmers had no choice except to pour their livestock into the markets without regard to demand. Farm prices tumbled. I was then making my living on the 125-acre Ohio farm where I was born. Hogs were the farm's principal product. My half-fattened spring shoats were worth twenty-two cents a pound on the first of August. When they were ready for market in early October, ordinarily a peak time in swine prices, they sold for eleven cents a pound. The well-meant but questionable edict of a governmental agency had cut my year's wages in half.

I was one farmer who took a beating, but I was not alone. The crash in prices affected six or seven million other farms, and for many it was disastrous. Thousands who had gone into debt to buy land were unable to meet their mortgage payments. The sudden contraction of credit, intended only to check what appeared to be an inflation trend, pulled the bottom out from under prices of grain and hay, of eggs and milk and cotton, and no farmer escaped. A correction of the high price trend undoubtedly had been due after the war, but this was a smash rather than a mere correction.

Urban America underwent a brief jolt and then quickly resumed its prosperity. The automotive industry moved into high production. Other new industries got under way. Credit was easy for business expansion at home. Foreign loans stimulated exports and fancy schemes in finance. Part of it was sound prosperity and part of it was not, although to those who were gathering in the dollars it was hard to distinguish which was which and there was little incentive to bother as long as the dollars were expendable. The farm recovery was slow and never became complete.

A new word became common in the agricultural vocabulary. No one could discuss the condition of the farm business without saying something about "surpluses." There was a surplus of wheat and a surplus of cotton, and a surplus of whatever brought too low a price. Farmers were "overproducing" food in an underfed world. The "plight" of the farmer moved into the headlines and stayed there. "Farm relief" became a major issue.

Early in this period farm relief came to me in a more efficient form than reached most farmers. A telegram from New York offered me an associate editorship on *Farm and Fireside,* then well known as a national agricultural monthly. The job looked interesting and the salary sounded attractive.

Transplanted suddenly from the hog-lot to New York, I shortly found myself engaged in studying the almost countless plans for farm relief which were being thought up and publicized. Hardly a week failed to bring to my desk some mimeographed or printed scheme, a long letter from some hard-put farmer who was trying to think his way out of debt by legislation, or a visit from some advocate with an idea that he was sure would solve everything if our magazine would only devote a few pages to laying it before the people. The famous McNary-Haugen plan was one among the many, the one which was eventually promoted into the most vigorous support and widest renown.

II

Regretfully I had to decline to endorse either the McNary-Haugen plan or, with one exception, any of the other proposals. The exception was an export-debenture scheme which I thought might work temporarily under certain world conditions. I may have been wrong even about that. I could see no possibility that agriculture would be lifted by its bootstraps through legislative devices. The mistakes of statesmen had been primarily responsible for the difficulties of farmers. The big statesmen had created a war and the war had distorted the normal development of production. Minor statesmen, seeking to avoid one consequence of the distortion, had as usual created a worse trouble than the one they had tried to correct.

The mistakes of statesmen are unlike those of other individuals. An individual who makes an error is usually the principal sufferer himself, and usually can correct his mistake if he tries; perhaps he may even profit from it. When a statesman makes a mistake the whole nation suffers the consequences and no correction is possible. The mess he makes continues to be a mess.

No particular satisfaction was to be found at a desk hunting defects in the efforts of other men to be constructive. Several million farmers were receiving too little for producing the most necessary goods that enter into commerce. No one performed more useful work than farmers. That a normally efficient farmer's labor and investment deserved a reward at least equal to the compensations of a comparable ordinary city business could hardly be denied. I had no reason to suppose that I was bright enough to find an answer to the question everyone else had missed. I was anxious, nevertheless, to uncover some lead, however small, that might be developed into a contribution that would be sound even though it might not be complete. A multitude of separate and individual ailments, not a single disease, affected agriculture. The prospect of a panacea that would cure them all seemed completely illusory. That approaches might be found to improve some of the separate parts of the condition seemed reasonable. One night in Chicago in 1924 I found a clue.

Julius Barnes was making a speech before the annual convention banquet of the American Farm Bureau Federation. He was then president of the United States Chamber of Commerce. In business he was a wheat exporter; the world wheat outlook was his topic. His predictions were not cheerful. The world would buy and eat only so much wheat, he said.

His next sentence was the beginning of chemurgy, although I doubt that Mr. Barnes ever came to be aware of that. This is what he said:

"Unfortunately the human stomach is not elastic."

III

I knew, even then, that millions of human stomachs around the world were insufficiently filled. I knew, too, that other millions of people, though not hungry, were ill-nourished by badly balanced diets. These were conditions, however, not markets. Most of the hungry did not earn enough money to pay profitable prices for our food, while of those who had buying power many lacked education in the fundamentals of food and health.

Nevertheless Mr. Barnes's statement about the inelasticity of the human stomach seemed essentially sound. When a man became rich he still usually ate only three meals a day. Indeed I knew rich men who ate less than when they had been poorer in purse and better in health. But a rich man might buy several houses—a town house and a country house, with a camp in the north, perhaps, and a winter home in the south. He might buy several automobiles, several radios. He might buy and use any quantity of almost anything, except food.

So, why should not farmers be enabled to produce other things than food? Why should they be confined to one inelastic market when so many other markets appeared to be almost infinitely expansible? To the food demand nature seemed to have imposed an obvious limit. The only limit upon human capacity to consume non-food goods was purchasing power.

At this period in the mid-twenties one could see, too, that the advance of technology was likely to increase steadily the output of farmers, whether they produced food or something else. Tractors were rapidly displacing horses. Field equipment was being re-designed for tractor power. New farm applications for electrical power were appearing one after another. Science was improving the techniques of production. One farmer could produce more, by far, with these new techniques, than one farm worker only a few years earlier. The trend to efficiency appeared certain to continue. Certain things appeared reasonably sure to come about in consequence.

Either wider markets would have to be developed for farm products, or more rural people would have to quit farming and find other employment. A constantly declining farm population and a constantly rising urban centralization were not encouraging indications for the future of a strong and free America.

A few days after hearing his speech, I went to see Mr. Barnes at his offices in downtown New York. He expressed surprise that his offhand remark about the stomach's inelasticity had been regarded as important. Although disposed to agree that it suggested the development of non-food outlets, he confessed that he had not thought beyond the fact of the inelasticity.

Other work kept me fully occupied at the time but the idea of non-food uses kept recurring. Fibers, of course, already were important farm products, with cotton our leading crop and coming to be our foremost problem. I learned that my fountain pen barrel was made from casein, a milk product. I heard that some people thought paper could be made from cornstalks. Finally I outlined the idea roughly to George Martin, my editor, proposing an article in a memorandum (November 7, 1925) which said in part:

> . . . , the human stomach is inelastic. Domestic food consumption increases in quantity only about as the population increases. Can more of our farm production be diverted from food products to industrial materials? Cotton, wool, and flax, are for industrial use. Jardine pointed out the flax situation in his article. We usually have enough wool and cotton. But soy beans, for instance, now grown primarily for animal food, are useful for industrial purposes and I believe research would develop a much larger market for the oil. I don't know whether any governmental research is being made on this point. There may be other crops. If an inquiry shows that there is enough good material to justify, how about it?

Martin warmly approved my later verbal proposal to explore the idea as thoroughly as might seem appropriate. So I set out to spend most of a year talking with scientists and their associates in government, in colleges and experiment stations, in industrial laboratories.

"What is the biggest unsolved problem in the agricultural sciences?" was my indirect approach to an administrator in one of the Department of Agriculture scientific bureaus. He asked for a day or so to think it over. When I returned he gave me his answer.

"We don't know the cause of peach yellows," he said.

Imagination did not exactly run riot among the government scientists. One spent an afternoon telling me that years ago the Department had studied my idea quite fully. They had even made paper from cornstalks and straw, and had published a bulletin proving that while it could be done it could not be made to pay. He virtually recommended that I spend my time on some inquiry that might more likely be fruitful.

It is only fair to add that a dozen years later, after some millions of dollars had been appropriated for chemurgic research, this gentleman became one of the ablest and most enthusiastic of advocates.

A highly stimulating day was spent in Pittsburgh at the Mellon Institute. Dr. Edward R. Weidlein, the director, encouraged the idea of a full and open-minded survey, although he explained that no such projects had been assigned to the Institute by its industrial clients. He invited me to look around.

In one wing of that magnificent scientific establishment I saw people investigating sleep. Elaborate apparatus had been devised to determine and record the behavior of the human animal during his slumber. The purpose was to find facts about restful sleep, so that better mattresses and bedroom equipment could be made.

In another wing scientists were studying bread, its ingredients, and methods for preparing and baking the staff of life. Their objective, of course, was to discover how the baking industry could deliver a better loaf and produce it more efficiently.

A third problem under study was the killing of flies. Here men were trying to discover some better insecticide than a fly swatter to contend with this widespread and dangerous insect nuisance.

Those three research projects stirred an exciting train of reflections.

Sleep was a part of life, a universal experience which every human being who ever lived had shared. For uncounted thousands of years countless millions of people had closed their eyes at least once each day in their need for rest and comfort and peace. While I was thinking about it in my berth en route home, nearly two billion human beings were trying to relax for some part of their eight to twelve hours of sleep. A third of all human life was being spent in sleep.

Yet, there in Pittsburgh in 1926 I had seen the very first scientific effort in all history to discover every possible unquestionable actual fact about the conditions that contribute to sound sleep and true repose.

Undoubtedly, too, for as long as men had been trying to sleep their comfort had been disturbed by flies and other insect annoyers. I had just seen the first thorough and complete scientific study aimed at discovering an efficient insecticide that would kill the flies and mosquitoes.

Bread, certainly, was one of man's earliest prepared foods. Its beginning was prehistoric. The lack of bread or the bad quality of it had undoubtedly wrecked many a night of sleep, too. And I had watched men engaged in the first genuinely comprehensive scientific study of bread making.

Thereafter I was fully convinced that science could develop markets still undreamed of and unimagined for the output of the farms. No one could put me off by mentioning some little effort that had been tried and had failed. No one could any longer tell me that there was nothing to try. Everything, almost, was yet to be tried! The imaginations of men had not ever been stirred to begin to ask the elementary questions. Men had from time immemorial been raising wheat and rye and barley because they knew how to raise such crops while they knew nothing about how to raise and sell others. They had grown cotton and silk and flax, and sheared the sheep's wool, because those fibers seemed to meet their minimum needs. We had to find questions to ask that would shake agriculture out of complacency with its ancient businesses, complacency even with its ancient problem.

Back in Washington again I went to see my friend Bill Jardine, William M. Jardine, then the Secretary of Agriculture.

He caught some of the idea I tried to convey and promised to think about it. We agreed that large federal appropriations for government research in the field of new uses would probably have to wait for a widespread agricultural demand. Bills to appropriate millions of dollars were not passed casually by Congress in those days. I determined that some day the demand for research funds would arise.

Meanwhile, I wondered if private funds to begin such research could not be obtained. Perhaps some of the business interests then denouncing the same legislative schemes that I thought unsound could be persuaded to support a constructive alternative. I had no knowledge, however, of how to go about such an undertaking.

"You ought to talk to Hoover about this thing," Jardine said. He made the appointment and I went over to Mr. Hoover's big plain office in the Department of Commerce, then in a rented building at 19th and Pennsylvania.

Mr. Hoover looked out the window while I described my belief that research could find non-food uses for farm products and help agriculture to escape the consequences of producing more food than could be sold profitably. Shortly his chair swung around and he talked. He thought the idea was sound. Science was opening up countless new opportunities in industry. It should do something along that line in agriculture. But research was slow, and expensive. Much more ought to be done. He named some people he thought I should see.

"Maybe you can tell me something—," he said, and for three-quarters of an hour he pumped me dry about other agricultural matters he wanted to know about.

The next Congress received a request from the Department of Commerce for $50,000 to be used by the Bureau of Standards in investigation of industrial uses for agricultural raw materials. I have since seen Mr. Hoover many times but have never asked whether that request bore any relation to my first visit with him.

IV

Positive then that something could and must be done, I wrote a modestly interrogative little editorial. The files of *Farm and Fireside* show that it appeared in the issue for October, 1926, which was off the press and mailed by the twenty-fifth of September. Here it is:

DO WE NEED THIS FOUNDATION?

The stomachs of the world hold only so much; the consumption of industrial products has no limit.

Industrial uses for farm products, adequately developed, would extend immeasurably our agricultural markets.

The commercial manufacture of paper from straw and cornstalks, of alcohol from fruit and vegetable wastes, and of chemicals from by-products of the soil, has long been held out as promise to farmers. The predictions are slow to materialize. One's questions are usually answered with a statement that, while chemistry has accomplished these things, commercial production is not yet practicable or profitable.

Here is a big want in a vast field for study to which existing agencies seem not to be equal. The situation might well be met by the creation of a well-endowed foundation with income sufficient to employ scientists competent to find and remove the obstacles that now prevent the profitable utilization of farm waste products.

With agriculture's needs for wider markets so acute it is time ways were found to go ahead and make commercial production profitable. Possibly no sufficient incentive now exists for competent individuals to follow through with the necessary additional research. In some cases more research may be needed less than business encouragement.

Farm and Fireside believes that if a survey of the facts reveals that a foundation could meet this need, money for the endowment can be found. Nor would all of it have to come from the usual sources of philanthropy; farmers themselves would contribute according to their means in order to show their approval.

That seemed totally inadequate, although a few letters from readers indicated germs of interest. A longer article was promptly prepared. Elaborating the basic argument a little further under the title, "Wanted: Machines to Eat Up Our Crop Surplus," this became the leading feature in the January, 1927, *Farm and Fireside,* which readers received with their Christmas mail.

Other articles and editorials followed month by month. A small crusade was being started.

Here and there the idea was occasionally discussed in newspapers, or one of our pieces was quoted. Clifford V. Gregory ably supported the proposals in the *Prairie Farmer.* I wrote resolutions which were adopted by the National Grange and American Farm Bureau Federation.

Someone sent me an article from the *Dearborn Independent.* The writer predicted that manufacturing industries would eventually turn to annual crops as major sources of raw materials. Nature, he declared, efficiently produced such compounds as cellulose, starch, proteins, sugar and oils, and organic chemists would learn to convert these into countless useful items. Feeding whole corn to hogs, he insisted, was an economic waste; let the chemist first process from the corn what he could use and then return the residue to farmers, who would have better hog feed after the industrial values were extracted.

The author's name was Dr. William J. Hale. His approach was directly opposite to mine. He was an industrialist, speaking from an industry viewpoint. He thought manufacturers, particularly chemical manufacturers, could profitably investigate agriculture as a source of raw materials. My approach was wholly from the side of agriculture on the hunt for new markets. He was interested in expanding industry. I wanted a more prosperous and stable agriculture. That these two separate approaches led directly to common ground was perfectly clear.

I knew too little about chemistry to accept or deny all of Hale's argument, but his article revealed that he knew much that I wanted to learn. He looked like a prospective recruit to my campaign. He was, I learned, associated with the Dow Chemical Company, and at the time chairman of the organic chemical committee of the National Research Council. After an exchange of letters we met in Washington.

I found a jovial intellectual dynamo who loved nothing more than to startle listeners, scientific or lay, with violent assertions and far-fetched predictions. "The steam engine! Oh ho, that's dead; it's out! You won't see any more steam engines," he might say. I finally learned that he meant it was no use to think about steam when more efficient power seemed to be in sight. It was evident that Dr. Hale would often enough perplex people with his obviously fantastic remarks, but he would also make them think. He was a scientific agitator, or rather an agitator in science. His Ph.D. was genuine and so was he. I figured he would be useful.

Hale's Ph.D. helped to get my subject before new audiences. He was not accustomed to writing for the popular magazines, while because I had no scientific standing my articles were not often accepted. Working together we were able to get articles on the non-food utilization of farm products into *Collier's* and other places.

Thomas A. Edison, I read somewhere, was trying to find a farm crop that would yield rubber, so that the United States would have a domestic supply to maintain its transport in case of war. I hurried down to Ft. Myers, Florida, to interview the great old inventor.

"You're exactly right," he shouted, cupping his hand in front of his abdomen. "The stomach can hold only so much."

I came away with powerful new ammunition, not the least of which was the encouragement of his vigorous approval.

Henry Ford was visiting Edison at the time, which was late in February, 1928. He instantly agreed with my whole argument that since agriculture could easily produce more food that could be sold profitably, industrial uses not only ought to be, but could be developed to keep farm income on a more stable basis. He invited me to come to Dearborn.

"You know farmers are pretty important customers of ours," he said.

Whether that talk and our later talks at Dearborn gave Mr. Ford any ideas his marvelous mind had not already considered I have never known or asked. It was only important that he was interested, which meant that action would follow his interest.

The three men whom I regarded as the three greatest Americans then living and who had, I believed, the three most constructive minds in America—Edison, Ford and Hoover—had agreed that my idea was sound and that it was important. I had no more doubts, and I had a job that needed to be done.

The task was to promote support that would get research under way. Whether the research should be privately endowed, as my first naive hope suggested; whether national or state appropriations should be sought; or whether efforts should be aimed to arouse the direct interest of private industry, was not very clear. Perhaps all three methods could be developed. The only clear course was to keep hunting for facts and to continue to try to interest more people.

I decided to write a book. Doubtful that many would buy a book on industrial uses of farm products, and doubtful too that I had enough to say to make a good book on that single topic, I took a broader approach. The book discussed about all the then current agricultural questions. A section of several chapters explored new uses, new crops, utilization of farm wastes, and pleaded for more research on this whole front.

Too Many Farmers was published in the notable year of 1929, in the memorable month of October. Those who were interested in the stock market at that time will guess correctly that my tome was widely ignored by the business men and by many others I had hoped it would reach. A few influential people in agriculture read the book, however, and several who were thus exposed to the chemurgic idea began to give thought to its possibilities.

The depression discouraged hope that a foundation could be financed soon. Changes in the magazine where I made a living—even an advocate of non-food utilization of farm products has to eat—required close attention and limited the time I could expend.

Then Dr. Hale, whom no depression could depress, decided to write a book. He had eagerly added to his own great and learned store of opinions my belief that his beloved science, organic chemistry, could add solid and permanent strength to the agricultural economy. For a title to his book he coined a new word. The title was *The Farm Chemurgic*. He had combined the Egyptian root word *chem* with the Greek *ergon* to create a short expression meaning "to put chemistry to work for the farm." Hale's book was given a wide free distribution by the Chemical Foundation and by it many more imaginations were fired.

V

During 1934 I came to the conclusion that no substantial progress was to be expected unless an organization could be set up especially to push research for new uses. The farm organizations, though mildly favorable, had their legislative and other programs to promote and were not vigorous on this matter. Privately the organization leaders thought that, while sound enough, research was necessarily too slow to meet the more dramatic immediate problems. Scattered across the country, however, were men who had become convinced that something less dramatic and more sound would more effectively meet the acute and urgent wants of farmers for wider markets. Enough of them, I thought, were attracted to research for new uses to be brought together into a national group that could find ways to forward the purpose. I had not, however, thought of a way to finance a meeting of such men nor to finance a continued effort after they had met. There was not much use in having a meeting unless the way was clear to do something more than talk.

One day in January, 1935, I encountered Hale in the Cosmos Club in Washington. Both of us were lunching with others, but we paired off for a few minutes.

"Isn't it time to organize this idea? Can't we find an angel for holding a meeting?"

"Let's go see Garvan," said Hale.

CHAPTER III

Chemurgy Is Organized

I

FRANCIS PATRICK GARVAN was president of the Chemical Foundation. He was a rich, humorous, patriotic, philanthropic, fightin' Irishman.

Back at the time of the Harry Thaw trial he had been with William Travers Jerome as assistant district attorney. During the war he had been first assistant alien property custodian and then custodian. Having seen the fearful cost of his country's dependence upon German chemicals, he had decided that the United States should not again run such a risk. His arguments won President Wilson and Congress to the idea of a chartered body which should own the confiscated German chemical patents and administer them in the public interest. Thus the Chemical Foundation was established. An income of more than $18,000,000 poured into the Foundation during the lives of the patents. Garvan poured it out to support research in fundamental science, in medical science, and to build up public appreciation of the importance of science in a growing nation.

The idea for scientific creation of new economic enterprise in agriculture captured Garvan instantly. He was quick to grasp the whole concept and, for him, to believe was to act.

The idea had also been seized upon with avid enthusiasm by Carl B. Fritsche, an engineer and old friend of Dr. Hale. Not being fully engaged at the time, Fritsche offered to go to work. A national organization was the objective, but it was decided to undertake first to bring together a conference of important national leaders.

Hale and Fritsche took the conference idea to Henry Ford, who said: "Hold it here at Dearborn and we will help a little."

Invitations were mailed hopefully for a Conference of Agriculture, Industry and Science, which was Fritsche's wording. The sponsors were Henry Ford, the Chemical Foundation, the National Grange, the American Farm Bureau Federation, and the Council of Agricultural Organizations, a committee headed by Clifford V. Gregory. We agreed to be well pleased if seventy-five came to the Dearborn Inn on May 7 and 8, 1935.

More than three hundred came. Ford's name on the invitations had made them important. Among those who registered were presidents of the leading railroad and automobile companies, chemical executives, college presidents, heads of research institutions, and a good number of influential farmers.

In the opening address I undertook to declare our objective:

> We have developed a tradition here in the United States of building business on a basis of low costs, large volume, large turnover, and reasonable profits. It is the purpose of this conference not only to suggest the possibility that agricultural prosperity may be rebuilt along the same principles, but to point out the practicable and feasible means by which this desirable end may be accomplished.
>
> We are today utilizing but a small portion of the productive power of our cultivated soil, and an even lesser proportion of the productive power of our agricultural energies. We who are food producers have felt ourselves limited by the inelasticity of human stomachs. Few of our customers, however rich, seem to want more than three meals a day. And farmers can feed the country with one hand, with half the energies they have available.
>
> In contrast, the American people have an apparently infinite capacity, given adequate purchasing power, to consume the products of industry and of agriculture other than food. Therein lies

an opportunity of greater magnitude than we may comprehend without careful examination.

We are met for today and tomorrow to study the superb prospect of these new opportunities. If they are as sound and as far reaching in their potentialities as some of us here believe, these opportunities will stimulate confidence in our country's future. Carried out, they will aid agricultural purchasing power to forge its way back to normal, if not to new heights.

As farm purchasing power rises, industry will have fast-widening outlets for the products of factories. Employment will spread in ever-enlarging circles. Once again we shall approach a balanced national economy with agriculture, industry, science and labor serving each other to their mutual advantage and to the national profit.

A sound agricultural future for the United States is entirely possible, a solid and substantial future based upon the equitable exchange of commodities and goods with American industries. By diffusing prosperity amongst farmers, we shall assure prosperity for all. I submit to you, gentlemen, that the thesis of this conference today is a thrilling challenge to our ablest scientific and economic statesmanship.

II

For two days speakers described present and possible developments in chemurgic types of research and industry. Network and local radio broadcasts and excellent news coverage carried the story over the country and aroused interest far beyond the attendance. Col. Frank Knox, Irenee duPont, Dr. Karl T. Compton were among the more eminent speakers. Mr. Ford signed the check for a luncheon to the entire group and put a fleet of automobiles at the disposal of those of us who were directing the affair.

One resolution was presented and adopted. The formation of a committee, to be appointed by Mr. Garvan, was authorized for the purpose of carrying on the ideas discussed at the conference.

In New York the following week we chose the committee with care. In June the members assembled to form a permanent organization.

The liveliest differences of opinion arose over the selection of a name. Dr. Hale wanted his coined word to be used. I was against it, on the ground that it was wholly unfamiliar to the public, not in any dictionary, and that it had a phony ring which would associate an entirely sound and conservative idea with such spurious panaceas as technocracy. Finally I lost the argument to myself on the point that "chemurgic" was short enough to fit into a newspaper headline. No copy desk could put into headline type all of "non-food utilization of farm products," nor any other phrase I could find—and we were going to need newspaper articles. So the committee became the Farm Chemurgic Council, to which later the word National was prefixed.

Garvan announced that the Chemical Foundation would pay the expenses of the organization for one year. Fritsche immediately opened an office at the Dearborn Inn, a good place from which to capitalize on the success of the conference. The Sears-Roebuck Company paid for printing several thousand copies of the conference proceedings which, when distributed, attracted the interest of many new people, especially among farmers. Every Grange in the country received one.

Dr. H. E. Barnard, a chemist and a good speaker, joined the staff as a science advisor. Hugh C. White took charge of publicity, and other help was employed.

A demand soon arose for local and regional conferences. Meetings were held at Pensacola; Beaumont, Texas; Jackson, Miss.; Macon, Ga.; Alexandria, La.; Fresno; Omaha; and elsewhere. Usually these were two-day sessions with plenty of time for agricultural, scientific and business people to discuss fully the chemurgic possibilities of their areas. More than one permanent convert was won by putting him on a program where he talked himself into an enthusiastic conviction.

The second Dearborn Conference was called in May, 1936. The advance registration revealed that the inn at Dearborn would be swamped, so the meeting was hastily moved to a hotel in downtown Detroit, where in 1937 the third conference also was staged.

A group of young research men at Iowa State College had in the early thirties published a bulletin which pointed encouragingly toward the possibility that one part of anhydrous alcohol made from corn or other starch crops could be combined with nine parts of gasoline to produce an improved motor fuel. If they were right, and if the cost of the alcohol permitted the blend at a commercially feasible cost which would lead to its general use, they had an answer to the troublesome problem of grain surpluses. Hale was an extreme enthusiast for the proposal and urged it with all his verbal vigor and chemical learning. Garvan, who was not a chemist, decided that alcohol-gasoline blends would solve the midwest's farm difficulties. He was equally certain that Dr. Charles H. Herty's discoveries for making newsprint from slash pine would free the South from the penalties inflicted by too much cotton. He determined to concentrate practically the entire effort behind these two projects, confident that they could rapidly be pushed to such proportions that chemurgy, in two fell swoops, would wipe out the major obstacles to a prosperous American agriculture.

I was delighted that so aggressive a leader was in charge. It was inspiring to see Garvan bully and coax and flatter old friends and new ones to persuade them to apply their influence or means. Dr. Herty's research had well proved his point, and Garvan was after the millions needed to finance a southern newsprint mill. Meanwhile he was pouring money into a plant to demonstrate that the alcohol fuel scheme was economically feasible, and into propaganda to enlist public demand for a blended fuel.

Seeing no reason at that time to doubt the probability that the alcohol men could prove their case, I publicly did what I could to support them. Privately I fought with Garvan over putting all our money and energies into these two still speculative efforts. Many chemurgic prospects besides newsprint and alcohol were promising, I argued, and some of them were sure to be successful if given sufficient attention. The chemurgic project was far broader than newsprint and alcohol.

"It is," Garvan agreed, "but these are the big ones. Let's do them first."

"Suppose the boys are wrong about alcohol costs," I contended. "Then where will chemurgy stand?"

"Then we'll have to do something else," he grinned. "I think they are right and anyway this is getting to be a grand fight."

I had lost arguments before, especially with the man who paid the bills. And he was right about the growing magnitude of the fight.

The petroleum industry, naturally enough, had not welcomed the "power-alcohol" idea. The oil men were not easily convinced: indeed they were not convinced at all, that the new farm income the alcohol industry might create would more than offset a small reduction in sales volume. But they admitted that farmers bought about twenty-five per cent of all petroleum products and that farm prosperity would increase their business. The danger of political compulsion roused the industry to a state of active alarm.

This pleased Garvan. Here was some one to fight against and he cheerfully fanned the fires of conflict, all the happier because the foe was rich and powerful. He built the scrap into magnificent proportions.

All the officers, board members, employes and participants in the Farm Chemurgic Council were individualists and none of their utterances were under either censorship or control. Some of us did not hesitate to compare our program of creating new wealth out of the soil with then current policies of restricting production. Our comparisons, even those most judiciously phrased, were not favorable to the administration. Before long we were listed as political enemies and the sharp hatchets of party leaders were whetted up to take our scalps if they could be reached. Thus we acquired not one but two rich and powerful enemies.

Garvan continued to finance the Council through the second year and part of the third. The Foundation's income had diminished to a trickle as its patents expired. He told the staff they would have to look at once for new sources of support, and that they must curtail activities, which had cost about $125,000 annually.

Then in November, 1937, sudden death struck Mr. Garvan down.

III

A gloomy group gathered for lunch the day following the magnificent funeral for Mr. Garvan at St. Patrick's Cathedral. Without a leader and without money, the future of the Farm Chemurgic Council appeared, to say the least, uncertain. Finally it was proposed that I, as the original proponent of the Council, should assume the presidency. I asked for twenty-four hours to think.

The decision was not made easily.

The Council had no money. Worse, there was already a $20,000 deficit which even with good fortune and the most economical management, was bound to be larger before it could be reduced.

The Council had virtually no contributors and virtually no paying membership; therefore practically no prospective income.

These facts had to be faced. No one was to be blamed. The Foundation had paid the bills as long as it could and there had not been time to put Mr. Garvan's new plans into effect.

Further liabilities were two red hot controversies. The petroleum industry's resentment was certain to reach far in influencing prospective contributors, especially as it was an important customer of most of them. Political hatchets would be out for our friends as well as for the Council.

The outstanding asset was a sound idea which was gaining momentum. For more than ten years I had fought to advance the idea thus far. I could not refuse to meet the challenge to carry ahead. Next morning the secretary wired the members of the board and obtained their approval. As rapidly as possible outlays were reduced, resignations of the higher-salaried staff members were accepted, and the Dearborn offices, too expensive for an insolvent concern, were closed. A small space was rented on the Chemical Foundation's floor in New York, not too far from the building where I worked.

During the previous year a dignified gentleman, engagingly suave, jovial and sincere, had called several times to enlist my participation in the worthy efforts of a foundation by which he was employed. Not wishing to refuse him outright, I had employed the counter-technique of telling him how important chemurgy was to the American future. One day he said with evident earnestness that he would like to work for so great a cause.

Recalling that remark, and that he had previously been engaged in money-raising, I sent for him, gave him the black truth about the Council, and asked whether he was still of the same mind. He was. He stipulated that he should receive a straight salary with no commissions or percentages. I told him there would be no salary until he replenished the treasury and that the replenishments would have to be divided with other staff members. He chose "Assistant to the President" as his title and went to work. His name was John W. Ticknor; now he is also the treasurer, with a surplus and reserve fund to the Council's credit. Without his dogged persistence, marvelous capacity to make and keep friends, and his persuasive ability to convince corporation executives and watchdogs that they want to help advance the chemurgic cause, I do not see how the Council could have survived. The sincerity of John Ticknor's interest is attested by his refusal of larger salaries even when the going was hardest, and the soundness of his methods is endorsed by the nearly automatic annual renewal, frequently with increased checks, of ninety-five per cent of the memberships he has obtained.

IV

The next undertaking was to attempt to liquidate the two controversies without concession. While two good fights might have been assets in the skilled hands of a great battling Irishman like Garvan, they were liabilities to a cautious Scotchman without Garvan's talents and resources.

Arrangements were made for an invitation to lunch from the petroleum industry's outstanding spokesman. He asked what the Council's future policy would be regarding alcohol for motor fuel.

"To try to find the facts," I said in substance. "If our fellows are right, you will have to join us; if they are wrong, we can't hurt you."

He conceded that was not unreasonable.

"Now let's define our fighting ground, if we have any fighting to do, and confine our disagreements to that area," I proposed. "Then let's discover our common ground and work together on that." I emphasized his industry's large reliance on the farm market, which should become a better market if any of the non-alcoholic plans of chemurgy were able to add to agricultural income. I mentioned certain researches which, if successful, would directly increase the use of petroleum as well as of farm products. One of these was cotton fabric for improving the durability and lowering the maintenance cost of bituminous road surfaces, a project which since has not proved up to the tests then reported.

No promise to suspend industry hostilities was made, but he agreed to talk further with his people. Through the years the petroleum industry has shown increasing interest in the broad objectives of chemurgy. A few companies have become members of the Council. Lowered costs of gasoline production have abated the apprehension of immediate or subsidized competition.

Late in 1945 the American Petroleum Institute set up and financed an active Agricultural Development Committee to seek to increase the industry's utilization of farm products.

Next I went to Washington and ate a lunch with the then Secretary of Agriculture. Henry Wallace and I had always been able to meet on a personally friendly basis, with a certain perhaps grudging mutual respect, despite remotely different premises, thought processes and political viewpoints. To him I made a similar proposal. Both of us believed strongly that more stable and higher farm incomes would be a national good. Both of us believed in scientific research. Why not work together on our common ground? If we disagreed on other points, why not agree to define them, segregate them, and confine our fighting to their restricted area?

He asked if we would continue to advocate domestic production of commodities normally being imported.

"Our philosophy inherently demands that we seek economic means, through research, to enable American farmers to produce whatever is needed by American consumers."

"That is in conflict with administration policy," Wallace said. "If you insist on that I don't believe we can work with you."

Controversy number two has not been liquidated, which may be just as well. It has been an asset.

Part Two

CHAPTER IV

The Cigarette Paper Story

I

THE cigarette paper story is a well-rounded example of chemurgic achievement and an almost perfect illustration of chemurgic philosophy. Other larger accomplishments benefit more people and strike with more dramatic impact on the national economy. No other development quite so neatly embodies nearly every principle of chemurgy. Here organic chemistry, plant genetics, modern engineering, and individual enterprise combine to enlarge farm income, to create new jobs and to insure an ample home-produced supply of a commodity important to millions of people.

Before the recent war, France supplied ninety per cent of the paper in America's cigarettes. In 1939 American production first began on a large scale. Cigarettes eventually became scarce, but never because the paper was not abundant. No shipping shortage deprived smokers of their cigarettes, because both the paper and tobacco were within the United States. The fall of France and the German occupation, which a year or so earlier would have created a real American cigarette famine, took place without diminishing the manufacture of tobacco into cigarettes.

Suppose the United States had by 1939 been equally well fortified by assured production within its continental borders of ample national supplies of other essential commodities—such, for instance, as rubber! One may speculate, if he wishes, as to how events would have been influenced had economic preparedness been followed as a public policy.

This new industry opened up permanent and stable jobs for more than seventeen hundred workers. These jobs, that did not exist in America before 1939, were brought into being with the new industry. These seventeen hundred will not be looking for new places, or for relief. Theirs are the solid, permanent jobs that an expanding new industry establishes.

Farmers benefit. Cigarette paper manufacture consumes quantities of field waste and pays for it at prices profitable to growers. A wholly new source of income, never before existent, has become available to farmers.

II

I first met Harry H. Straus, the founder of the American industry, in 1936. He was then, I had been told, manufacturing cigarette paper at Troyes, near Aube in France, where he had around a million dollars invested.

"My customers are all in the United States," he said. "I am an American citizen. I want to Americanize the industry."

Whether he was disturbed by the disintegration of French freedom and alarmed by the signs of war in Europe he did not remark. A man with his penetrating intellect doubtless had correctly appraised those conditions.

"My problem," he went on to say, "is raw materials. In France we use the old linen rags which are collected principally in Poland, the Balkans, and Central Europe. They are old rags, too, by the time we get them. The United States does not have enough linen rags, for linen is not so extensively used here."

Straus was thinking then that flax straw might yield a suitable material. He had found that farmers grow flax in nineteen states. Minnesota, the Dakotas, California, Iowa and

Montana plant the largest acreages. The pre-war yearly output was from six to fifteen million bushels of flaxseed. This was pushed upward to fifty million bushels in 1943. The seed, after crushing, provided the linseed oil of the paint industry. The straw had no commercial market and no feed value. Its disposal was usually a necessary expense. The slow-rotting fibers, if left on the ground or plowed under, were so troublesome to future cultivation that farmers usually raked and burned the straw. Linen flax, Straus knew, was a different strain of the plant, grown on only a few acres in Oregon. Production was expensive. The straw had to be lifted from the soil, roots and all, the straw retted in tanks and the fibers separated by laborious processes. The seed yield was small and after planting seed was set aside, there was little left for sale to the crushers.

Already, by 1936, Straus had established experimental plots of flax varieties on 600 acres in South Carolina, and was arranging for studies to be made in some of the agricultural colleges. His research men were examining other plants, seeking to discover whether a blend of seed flax and other fibers would yield a pulp suitable for cigarette paper.

Three years later, on October 1, 1939, I met Mr. Straus again, at Asheville, North Carolina. We drove some forty miles southeastward to the village of Brevard. A short distance from the town a meadow spread out from the very edge of the Pisgah National Forest. Alongside the meadow flowed the Davidson River, a substantial stream of pure, cold water moving down out of the forest watershed. Close by the river stood a sparkling, shining new five million dollar factory.

We stepped first into the warehouse. There, piled high to the rafters, were bales upon bales of flax tow. Half of the bales were silvery gray. These came from the flax fields of southern Minnesota. The others were tawny yellow, and had been shipped from the rainless, irrigated acres of California's

Imperial Valley. The long and patient search by the Straus technicians had discovered that by blending these two fibers they could obtain the precise pulp characteristics required for their finished product.

From the warehouses the bales were conveyed to digesters and beaters. Chlorine hypochlorite added to the mass in these stages helped to bleach the fibers to the brilliant, unmodified white of the final paper. A measure of calcium carbonate regulated the porosity that is a factor in making the paper burn evenly with the tobacco.

The wet pulp, two hundred parts of water to one part of fiber, was being spread into the wet ends of the block-long paper machines. From the other ends came the huge, tightly-wound rolls, each more than nine feet wide, of finished paper, unvaryingly white, unvaryingly thin—less than one one-thousandth of an inch, which is less than the diameter of a human hair; uniform in opacity and in every other requisite quality.

The big rolls, more than wide enough for tablecloths, were shortly sliced into bobbins, the width of each being the exact circumference of a cigarette. Shaped rather like multiple-sized rolls of moving picture film, the bobbins were sent on to the tobacco factories where each would wrap 85,000 cigarettes—4,250 packs of twenty.

At that time, in the autumn of 1939, the factory employed 900 young men and women. Not a single one of their jobs had been in existence in America six months before. They had new employment, created by science and enterprise, out of capital, high managerial skill and a previously wasted agricultural material.

I looked around at the busy workers, and watched the paper rolling up steadily from the great machines.

"We made our first shipment on the day Hitler's tanks rolled into Poland," Harry Straus remarked.

III

Since that time the factory has been more than doubled in size and capacity. The output is now about fifty tons of fine papers daily. Enough paper for 400 billion cigarettes a year is manufactured. A separate operation produces enough booklets daily to allow each of 250 million smokers to roll a cigarette of his own. Stored ahead, ready for instant call, are eight hundred thousand pounds of the paper. Almost forty thousand tons of the raw fiber are stored in twenty-five warehouses.

During the first World War the cost of cigarette paper rose 600 per cent. During the recent war there was no increase in price—and the quality of the new domestic product is decidedly superior.

Writing, air mail and fine text papers now also are made from flax, at Pisgah Forest. The volume of these products and the demand for them have grown to such an extent that a hundred and sixty distributors throughout the land serve to pass them on to the public.

Flax from American farms, processed at Pisgah Forest, went with the American soldier and sailor, of course, wherever he went and wanted a smoke. In another form, too, the new flax paper, followed him into many a foreign land. Military (invasion) currency was printed on flax paper by the United States Government. Now it is a part of the regular currency, and you may lay down a flaxen dollar bill to buy cigarettes wrapped in flaxen paper.

No farmer could afford, certainly not now and probably never, to grow flax entirely for the straw used as a paper ingredient. Nor is there any occasion to contemplate doing so, since linseed oil is a staple commodity not likely to be replaced. However, as a source of by-product income from an already profitable crop, the straw sale steps up the percentage of profit and affords additional inducement to improve the quality of production. The seed itself in the United States, from 1934 to 1941, ranged in price from $1.42 to $1.90 a bushel, and in the latter year brought farmers $54,311,000. Ceiling prices in 1945 were $3.05 to $3.30 per bushel.

About one half ton of flax straw is the average acre yield, with a maximum that reaches beyond two and a half tons. The straw, when baled and delivered at the local mill, is usually paid for at rates of from $13.00 to $16.00 per ton. The price varies according to the quality, cleanness, and the moisture content of the straw. The best straw is that threshed by a machine equipped with rubber rolls which do not break up the fibers, and which also recover a larger proportion of the seed and crack less of it.

Farmers in Minnesota and North Dakota have found that after paying the labor and other costs of raking, baling, loading, trucking and shipping straw to the mill their net return has averaged about $2.50 per ton. A California study reports the net at from $1.00 per acre upward. "Considering that the grower is usually put to considerable trouble and expense to burn off this straw," says S. C. Heth in *Agricultural Engineering*, May, 1945, "if he doesn't bale and sell it, the total value of the straw to the grower is greater than indicated by the sales prices."

Utilization of flax straw for cigarette paper had the effect of directing the attention of other users to this source of raw fiber material. Considerable quantities of shives from tow plants are now being utilized by manufacturers of wall board and corrugated board. An unprecedented increase in the demand for flax tow for automobile-body insulation, etc., is predicted by Mr. Heth, who as harvest equipment engineer for the J. I. Case Company has closely studied the development in flax straw consumption, with an eye to the market for improved harvesting machinery.

The consumption of flax straw, the product that once had to be raked and burned, has for the one purpose of fine flax papers risen to around 300,000 tons per year. In Minnesota ten plants are operating with an approximate annual capacity of 400,000 tons of straw, twice the number of plants and five times the capacity existing only five years previously.

A recent observation by Mr. L. F. Dixon, vice-president of the Central Fibre Corporation, an Ecusta subsidiary, reflects an aspect of the economic effects that rise from this new waste-consuming industry. "By increased efficiency," Mr. Dixon said, "in tow manufacture and paper manufacture the net return for straw to the farmer has been increased from 50 cents per ton to $2.50 per ton, and we are definitely not satisfied with this. We wish to call to your attention, however, that the ton of straw on which the farmer nets $2.50 costs from $12 to $18 by the time it reaches the processing point. From the moment the straw begins to move out of the stack or from the field, costs mushroom at an alarming rate. By the time 345,000 tons of 1945 straw are purchased and about 58,000 tons of paper stock fiber are baled, this material will have taken on an investment of over five and a quarter million dollars. Then it will cost an additional half million to move this fiber out of Minnesota to the paper mill; over half a million is expended during the moving of this material by rail within the state."

Behind all the expansion of flax paper production Mr. Straus maintains a comprehensive laboratory and research organization. A geneticist on the staff has produced thousands of hybrid varieties. These are analyzed and evaluated, and the better ones moved out to field trials. Constantly sought are varieties that yield seed more abundantly, grow with better qualities of straw, and resist disease damage more vigorously. While he is not in the oil business the seed yield is of great interest to Straus, because more profitable crops encourage

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farmers to take greater care in cultivation and to produce cleaner fields.

Plant pathologists probe into the wilts, rusts and diseases to which flax is susceptible. One of their less pleasant experiences was to discover in California flax fields a sclerotial disease hitherto unknown to the crop in this country. New varieties from the geneticists must resist these diseases as well as anthracnose.

Separation of the fiber from the woody shives (the process is known as decortication) has been made easier by special machines developed by Straus engineers. Varieties which separate more readily are also among the objectives of the geneticists. Efforts are being made to improve the equiment with which the straw is threshed and handled.

Weeds are a serious and constant problem in flax fields. The young flax plant starts its growth more slowly than most crops. Weeds, leaping up more quickly, have a chance to seize upon the light, moisture and fertility available; they readily overshadow or even extinguish the flax plant. The extent of this difficulty is indicated by the fact that more than 41,000 tons of dockage (weed seeds and other foreign material) were reported at Minnesota terminal markets in one year, equivalent to 11.3 percentage of the shipments. Freight car space for the dockage alone was estimated at 950 cars and the cost of hauling the waste material at $138,000. Mr. Straus not only can make none of his fine papers out of the weeds, but must encounter trouble and expense to eliminate them from the straw at the tow mills. Their presence necessarily reduces the seed yield and correspondingly lowers the return to the farmers, producers of the straw. From every standpoint weeds in the flax field are a costly nuisance.

An aggressive war on weeds has become an important part of the Straus program. During the war Imperial Valley farmers were offered $1000 in War Bonds in a flax growing contest in which freedom from weeds was fifty per cent of the scorecard. Better cultivation methods, with especial emphasis on sprouting and killing the weeds before the flax seed is planted, are vigorously advocated to growers. Use of the new chemical weed annihilators, which are effective on the broad-leaved weeds, is encouraged. Clean seed, of course, is insisted upon. A recent innovation consists of planting flax in rows so that it may be cultivated like corn or cotton. While increasing the labor requirement, higher yields have thus been obtained with much greater freedom from weeds.

Cellulose chemists constantly study the raw material and the product. The engineers, agronomists, pathologists, geneticists and chemists develop joint improvement measures. Each keeps in touch with progress elsewhere that concerns flax. Chemurgic research seldom discovers a terminal point, for the frontiers must always be pushed back and a pot of new facts awaits at the foot of every rainbow.

IV

Harry Straus's Ecusta Paper Company and subsidiaries have been built with an investment that has become more than ten million dollars. Bankers and tobacco companies have shared his faith and his patience. Ideas, scientific facts, promotion, managerial ability, personnel development, money and the cooperation of varied interests have combined to perfect the achievement.

Out of it have come a new cash crop for farmers, permanent jobs for hundreds of workers, and an abundant supply, grown and manufactured at home, of a superior product for the American smoker of cigarettes.

Those interested in such matters may choose to note that the investment, assuming the round figures given here to be approximately accurate, is at the rate of about $6000 for each job directly created. This is close to the average in American industry. The direct employment, naturally, does not tell the whole story. A community of seventeen hundred well paid workers supports as many additional people in stores, personal services, transportation, education, entertainment and other forms of business. The creation of a new industry exercises a constructive lift that reaches far.

CHAPTER V

Corn, a Crop with New Ideas

I

CORN is at once one of the newest and one of the biggest of farm crops. By natives of the American continent corn was known and grown as a major food for centuries. Asia and Europe and Africa got on as well as they might with wheat and barley, rice and millet, rye and oats. For the settlers in America, corn was of high importance from the earliest colonization days. Not, however, until a century ago when the steel plow began to rip the prairie sods, did corn begin to approach the huge output and high eminence it has attained since then. Not until then did there begin to be a Corn Belt.

Norway and Burma, Manchuria and Java grow their own corn now; so does every one of the forty-eight states, and three out of every four American farms. More than half of the world's corn crop grows in the United States, and three-fourths of this corn grows in the fertile, heaven-favored heart-land that stretches from western Ohio to eastern Nebraska and Kansas, from southern Minnesota into northern Missouri.

Four-fifths of the corn grown in the United States stays on the farm where it grew, to be used as feed, food, or for seed. Of the fifth that is sold, normally a half moves only a few miles to neighboring farms. Two and a half (sometimes three) billion bushels are harvested each year from about ninety-one million acres. Industrial uses during some of the war years claimed more than half a billion bushels.

When corn does go to market, detectives might have difficulty in tracing the components of the grain to their eventual destination. The chemical constituents of corn, once the kernels are broken apart, find a multitude of uses. Corn is versatile in good works. The consumer may use the great American grain in his bread or candy, in the baby's formula or in the doctor's prescription, in his window shades or his mucilage, in his fireworks or in his fire water.

Of all the commercial uses of corn, starch is basic. Starch is the first and most abundant product from the separation of the grain into its parts. The dry content of the kernel is 80 per cent carbohydrate. A 56-pound bushel of corn will make 33 pounds of starch. Starch is eaten and starch is worn, and starch finds its way into hundreds of end products.

Although the United States is the greatest of corn-growing countries and blessed with an abundance of starch, for many years huge quantities of starch have been imported from halfway around the world. Chemurgy looked at that challenge and produced a story that is finally ready to be told.

II

The Rev. J. M. W. Farnham's business in China was to save the souls of the heathen. Frequently and impatiently he wrote insistent letters to the mission authorities back in New York, demanding that they send him more tracts in Chinese translation, more Bibles, more equipment with which to strengthen his arm as a stern soldier of the Lord.

No doubt he had, somewhere in the United States, been a farm boy. The scanty records which the church has preserved about him give no information about his background or interests. But from Shanghai one day he wrote to the Department of Agriculture in Washington on a topic that apparently he had never so much as mentioned to his religious sponsors; only the other day its existence was found to be news to them.

Accompanying the note, received in March, 1908, was a small package of corn.

"A peculiar kind of corn," the note said. "There are several colors, but they are said to be all of the same variety. The corn is much more glutinous than other varieties, so far as I know, and may be found to be of some use, perhaps as porridge."

What prompted the Rev. Mr. Farnham to take the trouble to forward the corn no one now seems to know. He had been acquainted with it, a later letter revealed, for thirty or forty years. Perhaps one of the far-traveling plant explorers of the Department, such as Frank N. Meyer, had disclosed to him at some gathering of Americans in Shanghai that the Department was interested in locating new plants of economic value.

Farnham's corn was planted and grown by Department people in the season of 1908. The next year they published a brief account of it (Bureau of Plant Industry Bulletin No. 161). The plants grown "proved to be unlike any of our cultivated varieties or those known from tropical America. They possessed a number of unique characters, no indication of which is found in any of the forms of Zea *mays* thus far recorded . . . Several of the unique features combine to enable the plant to resist the drying out of the silks by dry, hot winds at the time of flowering."

Moist silks at flowering time suggested that here might be a corn for the semi-arid southwest, where corn usually failed because at pollination time the silks withered so that the pollen falling from the tassels was ineffective and grain would fail to grow on the cobs. From Mokansan, China, on August 24, 1909, the Rev. Mr. Farnham, doubtless in answer to inquiries from G. N. Collins who had received the first package, confirmed the adaptability of the variety to Shanghai's hot south winds at the flowering time.

The 1909 publication noted that "Another noteworthy feature of this corn is the character of the endosperm, which is quite distinct from the horny, starchy or sweet endosperms of the varieties hitherto known in the United States. In view of the recent development of specialized corn products as human food, this unique type of starch may be of some economic importance."

That was an acute observation which waited more than thirty years for its confirmation. Farnham's corn eventually did its small part to help his native country win a war. It now promises an important and profitable enterprise in American agriculture, may change the character of a portion of international trade, and may eventually force an improvement in the living standards of another part of the Orient.

First in an attempt to develop a corn for the dry regions, and later because of its genetic interest, the plant breeders kept Farnham's corn a-growing. Because the cut surface of the kernels gave the appearance of a hard wax, they called it waxy corn, though it contains no wax. A notable characteristic that soon became apparent was that when grown in proximity to ordinary corn, where the pollen fell upon the waxy silks, the waxy form disappeared and the grain became like ordinary corn. This recessive habit presented a problem when the real economic value of waxy corn was finally disclosed.

III

Valued for its constant genetic interest, waxy corn for thirty years presented no commercial temptations. New observations were noted from time to time about its nature. When stained with iodine, for instance, the cut kernels did not turn blue as do the kernels of ordinary corn. Instead they colored red-brown. Certain types of starch were known to exhibit the same color reaction to iodine. Starch chemists thought the fact might have significance.

During these years the use of starch in American industries had been rising notably. The total consumption for all purposes had risen from eight hundred million pounds in 1922 to a billion and nearly three hundred million before 1940. Production of corn and other domestic starches during the same period had gone from more than six hundred million to more than eight hundred million pounds. The gap between domestic production and domestic consumption, all the time growing wider, was being filled by imports, nearly all of which were of tapioca and sago starches, coming mainly from the Netherlands East Indies.

The cassava plant, a native of South America, was carried to the Asiatic tropics, probably by economic adventurers in the early days of exploration. So also, probably, were species of the sago palm. The cassava root made itself at home in the old world soils and grew abundantly in the days of long sunshine and high humidity. European imperialists found that tapioca, the product of the root, lent itself to export. Plenty of cheap labor was available for exploitation. The imperialists set out to saturate whatever world markets could be found.

As a food tapioca was known to American tables, and its sale for that purpose was expanded. As an industrial starch, so cheap a product readily made its way into widening use. Not only was it cheap, but for certain purposes it was superior. Corn starch, for instance, and potato starch, would not do as well as a remoistening glue. Consequently when an American licked a postage stamp or closed an envelope he was likely to be consuming tapioca starch from the East Indies. Purchases of tapioca for the manufacture of adhesives and paper sizings became immense. Importations in 1922 were barely one hundred million pounds, but by 1937 they had exceeded half a billion pounds. Because of their particular qualities they were not regarded as competitive and were admitted without duty.

Until about 1930 the price of cassava starches had been about the same as that of corn starch. Then the price was lowered and held at about a half cent per pound below corn starch. The effect was a steady increase in the proportion of cassava and the corresponding replacement of corn starch in a market that was expanding. Starch dollars were going to Java instead of to the cornbelt.

Meanwhile the advances in carbohydrate chemistry began to illuminate the scattered observations that had been made regarding the characteristics of waxy corn. Dr. R. A. Brink had noted as early as 1926 that starch in waxy corn was in some way different. In 1936 it occurred to Dr. R. M. Hixon at Iowa State College to mill separately one-bushel samples of several kinds of corn—the regular dent, flint, flour, sweet, pop and waxy. The starch from the waxy bushel was distinct from all the others. Dr. Hixon was setting out to discover more than was then known about the organic and molecular structure of starches. The two crude components of starch now recognized are known as the straight chain fraction and the branched chain fraction. The waxy corn starch which Hixon made was composed almost entirely of the branched chain fraction. So is tapioca. The other starches do not exhibit the branched chain characteristic in their molecular make-up, though the waxy characteristic does occur in strains of sorghums, rice, millet, coix (Job's tears) and barley.

IV

It is probably impossible to determine who first incubated the idea that there might be a genetic variety of corn with physical characteristics similar to those of tapioca. The recollection of Dr. Karl Link of the University of Wisconsin indicates that the question was raised as early as 1933 by an official of a starch milling company at Clinton, Iowa. Dr. Link recalls that in November, 1936, he presented the company with samples of waxy starch.

After the identity of characteristics in waxy corn starch and tapioca starch had been recognized, consideration was given in the milling industry to a research project looking toward extensive production of the corn. No one then knew how well waxy corn could be made to yield. The original Chinese strains, and most of those developed since, fell far short of equalling the productivity of ordinary corn. Apprehensive that the cost of commercial quantities would be too great to meet the low prices of tapioca, and considering that separate milling operations would be necessary, the industry's decision was unfavorable.

Nevertheless Dr. Hixon's findings stimulated a determination to breed up the waxy strains to commercial yields. Dr. Merle T. Jenkins in 1936 started introducing the waxy character into some of the standard varieties. In 1939 Dr. G. F. Sprague expanded the effort. He grew two crops a year, one in the field and one in the greenhouse, in order to speed up the procedure. By 1941 he was able to count in his possession 335 seeds of one cross, and 3800 of another. He had also 34 pounds of one double cross and about 100 bushels of another.

Of the 100-bushel lot, half went to the U. S. Regional Research Laboratory at Peoria to be used for further studies on the chemical characteristics and behavior. Forty-seven of the remaining bushels were planted on three hundred and twenty-six acres of commercial fields. Out of this 1942 harvest 13,240 bushels were sold to the American Maize Company. Pearl Harbor had changed the economics of starch. The Netherlands India source had been cheap but it had not proved dependable. Starch with the branched chain fraction had become indispensable for too many uses, and the fortunes of war had given Farnham's corn its chance to last.

V

At this point a practical agricultural problem had to be worked out. Unless the waxy seed was planted in some degree of isolation, where it would not be exposed to pollination from the ordinary varieties of corn, the crop would be mixed and unsuitable for manufacture. D. Howard Doane of the Doane Agricultural Service was called in. He undertook to find farmers who would grow the corn and deliver an uncontaminated crop. Upon his advice it was agreed that the extra trouble was worth an extra price. He was authorized to contract with farmers at a premium of fifteen per cent above the general market value of corn, the farmer to choose his selling date at will within the fall period. In 1942 fifteen hundred acres were planted and harvested. The next year the acreage was pushed up to fifteen thousand, and since then has been at approximately that figure. The resulting starch production is very roughly estimated at upwards of ten million pounds per year.

Fifteen thousand acres is not, from the overall agricultural viewpoint, a very large patch among the ninety million acres devoted annually to the American corn crop. The significance of waxy corn, however, is not to be measured by the area of ground it occupies.

Most striking aspect of all is the nature of the scientific achievement. Maize, a plant of the grass family, yielding a great cereal grain, has assumed a major economic function heretofore performed only by a tropical tuber, the cassava. "It is," says D. Howard Doane, "as though plant breeders has hung a cassava root on the cornstalk instead of an ear!"

The accomplishment was so timed as to be completed at the period of utmost need. At the very time when the imported starch stocks were depleted, the waxy corn crop was ready to harvest. No guesses are worth much as to the relative importance of the innumerable indispensable contributions to victory in the war, but waxy corn was among them in one way or another. We were rescued in the nick of time by waxy corn, as by synthetic rubber, from the evil consequences of shortsighted dependence upon far-distant foreign sources for supplies of economically necessary materials. The accomplishment having been completed, the risk need not recur.

The prospect is now open for a wholly new market for corn, a market not competitive with any other American crop or product. The future may find waxy corn competing with sweet potatoes, but that story belongs to another chapter. Every acre of corn that replaces starch imports is entirely out of competition with other corn acres; it will make no contribution to future surplus problems. Not only is it out of such competition, but it is an acre that normally would have been in the competition, for waxy corn will necessarily be grown by better farmers on their better acres, as it is likely always to be a premium crop. The fact that its production requires a degree of isolation and a certain amount of special attention gives some assurance that, if grown at all, it will be grown because the market is willing to pay a little extra for the extra precautions.

VI

How many more than fifteen thousand acres can profitably be planted to waxy corn? The whole future of the achievement hangs upon factors which can not now be determined. In 1942 an article in *Industrial and Engineering Chemistry*, written by Drs. Hixon and Sprague, said:

> The annual consumption of three hundred and fifty million pounds of tapioca in the world's largest cornstarch-producing country may be attributed to two factors, prices differential and the properties of the starch itself. . . . The estimates of the quantities of tapioca required for purposes which cannot be readily replaced

by other starches vary greatly. Some place the figure as low as fifteen million pounds, if tapioca is considered indispensable only in the production of remoistening glues and certain food products. Other estimates place the figure as high as two hundred million pounds.

Should the lower estimate just quoted be the correct one, some twenty or twenty-five thousand acres would supply the irreplaceable quantity of starch, provided no imports were available. If the higher estimate is correct, three hundred thousand acres would be necessary.

However, it is generally assumed that imports will be resumed after the plantations of the East Indies are recovered by their former owners and shipping space becomes available. Tapioca is not only on the free list but by one of the executive "reciprocal" trade agreements is bound on the free list for the duration of the agreement. Power to make further agreements rests with the Executive until June 12, 1948. The Dutch imperialists are not likely to entertain any sentimental hesitancy in destroying our domestic waxy cornstarch market because of what American farmers and their sons contributed to the liberation of the Netherlands and their empire, or to feeding the populations of that empire. They will move into the duty-free American market as quickly as they can, and if necessary will lower their prices long enough to eliminate the danger of competition by American farmers if that seems possible. Should our governmental policies of obsequious servility to foreign economic aggressions be continued, few American cornbelt farmers will profit from the opportunity achieved by the perfection of waxy corn.

Survival of waxy corn as a farm enterprise may therefore depend upon two other factors. One is the possibility of improving the waxy hybrids to still higher yields, to a point where they can compete with the lowest price imported tapioca can face. The other is that for substantial uses waxy cornstarch may prove definitely superior to tapioca starch. Dr. H. H. Schopmeyer, Director of Research for the American Maize Products Company, says that for envelope gums "it seems definitely superior to tapioca because of the high degree of fluidity of the concentrated paste." He adds that, "Waxy starch has been found particularly useful in sizing high quality cotton goods. The goods seem to dry more readily than when sized with potato or tapioca, and as a result can be run faster on the slasher. The filming properties of waxy starch are also excellent and there is a minimum of shattering of starch from the thread." Among the promising uses Schopmeyer also lists salad dressing, print gums, pie fillings, puddings of the tapioca type, and paper coatings.

That production costs can become lower on American farms than with the exploited labor of the East Indies seems unlikely, although not impossible. The mechanization of rice production in California long ago resulted in exports to China and Japan, where their hand-grown crop was undersold by the American rice. The prospect that waxy starch can hold some of the American market because of superior adaptation to specific purposes seems favorable, although the portion retained may not promise much expansion of acreage. Then there is, of course, the prospect that Americans will eventually revolt against the unsound policy of opening their markets recklessly to all the world and will insist on a tariff policy that will enable cornbelt farmers to enjoy some benefit from an American scientific achievement.

VII

A 32-year-old English baker named Thomas Kingsford landed in New York City on the twelfth of December of 1831, in the third year of the reign of Andrew Jackson. He went to work soon at his trade, but with no intention of baking loaves forever. He knew something of chemistry from a term of employment in a chemical factory in London. He had taught school. America was said to be the land of opportunity, and he was fully determined to prove that for him it was exactly that.

Kingsford found another job shortly, in a starch factory owned by a pleasant fellow-Englishman, William Colgate. Here starch was made from wheat. The processes and the product were so unsatisfactory that Kingsford, applying his chemical experience, set out to find something better. Corn would do better than wheat, he thought. After eight years of discouraging trials he was not so sure. Then came one of the happy accidents which not infrequently occur to researchers who keep on trying. He dumped some corn which had been treated with lime into a batch that was treated with lye. Thus, in 1842, he began making corn starch.

The generous Colgate let Kingsford keep the secret to himself while making the starch in Colgate's factory. By 1846 Kingsford decided to step out for himself, beginning at Bergen, N. J., and two years later set up a larger plant at Oswego, N. Y. In 1850 he began marketing cornstarch food preparations with immense success. Colgate, meanwhile, returned to his principal interest, the manufacture of soaps and toilet preparations, a business in which now, a century later, his family name is internationally known.

VIII

The only real manufacturer of starch is nature. She makes it so generously that it is one of her most abundant compounds. The best man can do is to separate out the starch which nature has made. No one knows the precise make-up of the starch granule and no scientist, therefore, has ever been able to synthesize starch.

Since Thomas Kingsford's day the laboratory men have nevertheless added immensely to the knowledge of starch, and of its manufacture. They have put it to a myriad of uses of which he could never have dreamed. They agree, however, that he was right about corn. No other American natural product has yet approached corn as the raw material. Ninety-eight per cent of the starch processed in this country has been the product of corn. More than one hundred million bushels of shelled corn are received at the fourteen huge starch mills of the country each year.

More than a quarter of a billion pounds of cornstarch finds its way into the food supply of the nation.

Larger than the dietary use, by a moderate margin, is the quantity consumed by the foremost industrial buyer, the cotton textile industry. Starch facilitates the weaving and finishing of fabrics. A textile plant without starch would have as much trouble as a motorist without oil, for the twisting cotton fibers would otherwise be exceedingly difficult to manage.

Nearly another quarter of a billion pounds is demanded to keep garments in order. After textile manufacturing consumption, laundry use of starch is next in volume.

The third largest industrial need for cornstarch is in the paper industry. Much as a shirt is starched to improve its appearance, most paper is "laundered" in the making, the technical term being sized. Some two hundred million pounds of cornstarch are thus used, in addition to a number of other materials of agricultural origin.

Cornstarch is a component of dynamite, and it disappears as starch into insecticides and pharmaceuticals, into paint and soap and into a multitude of other products where its presence is essential but usually unsuspected by the ultimate consumer.

IX

Being a complex sort of a compound, cornstarch was inevitably destined to become more than merely cornstarch. The research chemist cannot resist the lure of the unknown. He will never be content until he has learned what starch really is. While pursuing the mystery, he has found new ways to turn starch to human usefulness; and in his pursuit he will without doubt discover other profitable applications.

An important chemical change in starch can be accomplished by heat. Metal tanks, round and open-topped, are equipped with scrapers to prevent the material from adhering to the tanks. Dry starch, or starch with a sprinkle of nitric acid added, fills the tanks. The heat, at from 100 to 250 degrees centigrade, may be applied for a couple of hours or for fifteen or twenty hours, according to the characteristics desired. The resulting products are dextrins, which are made to fit an enormous variety of specifications. Unlike starch, which will not dissolve in water, dextrins are water soluble, although not soluble in alcohol.

The great value of dextrin is that it is sticky. Adhesive materials hold the American standard of living together in countless ways. Dextrins are among the most widely used of the many kinds of adhesives. Corn processors produce well over 100,000,000 pounds of dextrins a year, and other millions are made from starch by other adhesive manufacturers.

Gummed envelopes, labels and stamps are among the common objects utilizing dextrin; in these instances the dextrin preparation is known as a remoistening glue. Paper boxes and paper products that are, in any way, pasted together, commonly use dextrin as the adhesive. Wood veneer glues are very often dextrin products.

Dextrin is highly valued as a binder to hold other kinds of materials together. A familiar example is the little Fourth-of-

July sparkler in which powdered metal and inflammable material are held together on the center wire by dextrin. Foundry molds may be held together by dextrin, and so may coal briquets and electric battery compounds. Dextrin is used in leather and window shades, and as sizing for the backs of carpets. The minor purposes served are countless.

Cane, beets and corn are the three great servants of the American sweet tooth. More than a billion pounds of corn syrup are made annually, and large quantities of dextrose, or corn sugar. Since these are almost entirely consumed as food, they do not properly come within the scope of chemurgy, which has to do rather with the non-food uses of plant materials.

From the germ, which is separated from the grain by flotation at the beginning of the starch process, a high quality salad and cooking oil is produced. This, also, is essentially a food product, although some of it finds its way into pharmaceuticals and into textile-making, while a portion of the lower-grade product goes into soaps. The hulls, fiber and gluten enter into livestock feeds.

X

The by-products of corn are highly interesting to the industrialist and the industrial chemist, for the simple reason that they are economically available. That is to say, corn is assembled in large quantities to make such a product as starch, for which established markets are stable. Certain interrogation points confront the manufacturers and the chemists constantly. Are there more uses to which starch or its products can be put? Are there higher uses to which it can be directed, uses that may be more profitable? And are the by-products being utilized to the best possible advantage? Is this complex combination of substances which nature crams into a grain of corn withholding, until man untangles one more of its mysteries, another product valuable to mankind?

Among the non-starchy components of the corn kernel is the gluten, a large part of which is of protein substances. One of these proteins is zein. It constitutes 65 to 70 per cent of the gluten, and is the only one of the protein substances which is soluble in alcohol.

At the Corn Products Refining Company, chemist W. G. Newkirk thought that zein, which had long been known to exist, deserved looking into. A process was devised for taking the gluten apart by stirring the whole gluten in alcohol until the zein was dissolved. This was followed by treatments to remove the coloring matter and oil, and then the alcohol solution was sprayed into cold water. The zein, not being soluble in water, separated as a solid. After being dehydrated it appeared as a cream-colored powder.

What good is a cream-colored protein made out of corn? Proteins are not uncommon; why manufacture another one? The curious truth appears to be that nature with her marvelous habit of putting atoms and molecules together in an infinite variety of combinations abhors the exactly identical. She seldom produces two identical human faces or figures. Likewise she seems seldom to implant quite the identical sets of properties in any two sets of substances, even though some are sufficiently similar to permit interchangeability of use for man's not always precisely exact purposes.

Protein, of course, is a broad term, just as human is a broad term, embracing an infinite variety of beings. As one remarkable individual in the large family of proteins, zein possesses at least three properties which are unique. These were described in a *Chemurgic Digest* article (Vol. 2, No. 14) as follows:

> First of all it (zein) is more chemically inert than other available proteins. For example, casein, egg albumin and gelatine can be cured with formaldehyde to form hard, water-resistant products.

In many cases, however, this curing action takes place so rapidly that it is difficult to control in commercial practice. Zein with its smaller proportion of reactive groups cures more slowly and the solution of zein remains in a workable stage for a considerable time after the addition of curing agents.

A second unique point is its solubility in alcohol. This solvent, which evaporates rapidly and which is relatively inexpensive, permits the use of zein in applications where high water concentrations are undesirable or where more volatile solvents present a fire or health hazard. This property alone is sufficient to set zein apart from other commercial proteins and to put it in a class with much more expensive plastics and synthetic resins.

A third valuable property of zein is its thermoplasticity. When plasticizers are added to zein, either alone or in the presence of alcohol, compositions are formed which will melt at a lower temperature than zein alone. In this way almost any predetermined softening point can be obtained. The value of such a property is self-evident.

The principal pre-war use of zein was to coat paper and paperboard for containers which were used to wrap or hold greasy foods, paints, and oil-bearing materials. The notable oil-resistant quality earned zein a big war job as a coating for papers which wrapped airplane and tank replacement parts. Zein-coated paper was used in many landing operations to seal in envelopes rifles and small arms so that they were completely protected from the moisture which might otherwise have made them unusable when needed.

A trade paper item, mentioning zein as a shellac substitute, said it was being used in "shoe soles and heels, cements, raincoats, mats, gaskets and rubber stamps. Packaging films, textile fibers and bottle caps may be expected later."

Zein is a characteristic product of the search for new chemurgic knowledge. In use it fits a human need hitherto not adequately provided for; its manufacture affords an additional outlet for a portion of the corn plant which had formerly little other market than livestock feed. The knowledge obtained in seeking ways to manufacture and commercialize zein is added to the broad base of facts upon which further progress is constantly being built.

XI

The number of named chemical compounds runs so high into seven-figure numbers that a thoroughly trained organic chemist may easily possess a professional vocabulary of forty or fifty thousands words among which practically none would have any meaning to the normally well educated layman. The interested non-technical observer frequently wonders by what processes of mind substances, apparently completely unrelated, are brought together to perfect successful chemical reactions. Evidently the chemist sometimes wonders too, for now and then he admits that a result came from a happy accident, or finds himself unable to account for the inspiration which led him to try a particular association of materials. Penicillin in quantity became possible only when the steepwater in which corn is soaked preliminary to making starch was added to lactose to provide a suitable foodstuff to nourish the multiplying mold spores. Dr. R. T. Cogswell, who made the discovery, says he has no idea what put into his mind the idea of trying steepwater.

Allyl chloride is a by-product of the petroleum industry. A group of chemists at the Eastern Regional Research Laboratory applied allyl chloride to starch. The two products would seem to have no association, remote or near, but they were nevertheless hitched together. The outcome was allyl ether of starch, or allyl starch, a gummy material which is not sticky. It is easily dissolved in alcohol and other organic solvents.

When a solution of allyl starch is spread on wood, metal or paper, and the solvent allowed to evaporate, a glossy coating remains. Then, when this allyl starch coating is heated for one to four hours at a moderate temperature, 175 to 210 degrees Fahrenheit, neither any known solvent, nor hot oil, nor even ordinary acids and alcohol can dissolve or affect it. A table top covered with allyl starch cannot be spotted or marked by either a hot dish or a cold julep.

The allyl starch solution will impregnate wood, paper or cloth, and make any one of them tough and wear-resistant. The gummy allyl starch itself, treated with sulfur and the other materials ordinarily used to vulcanize rubber, produces a mixture which when molded hot under pressure produces a rigid material which heat and chemicals do not seem to affect. The starch is also a remarkable adhesive for laminating paper, wood veneer, and textile fabrics.

Thus another new product, a product with a promising future, emerges when imaginative men in search of facts bring apparently unrelated materials together under controlled scientific conditions. Allyl starch is very new, and as this is written has not had time to make its way into commercial production. Its uses appear to reach a long way beyond corn's normal destiny in hog feed and corn bread. It was in the hope of such extraordinary and unpredictable developments that the idea of chemurgy was born and fostered; it is in the hope that many more such advances may be achieved that chemurgy continually urges more and more research into the marvelous raw materials which nature is willing to reproduce in unlimited quantities.

XII

On certain autumn days of each year, secluded amid the lavish comforts of a resort hotel the foremost carbohydrate chemists of America sit down to talk about starch. For four days they leave their families and offices, the laboratory routines and telephones. One year they may gather in the Royal Muskoka Hotel at Lake Rosseau in Canada. Another autumn will find them at French Lick in Indiana or at Pocono Manor in the Pennsylvania mountains. Lounging in informal ease, taking time out for golf and walks or even, perhaps, an interval of "elbow-bending," they lay before each other the successes, failures and problems of the previous year. The sessions are called the Annual Starch Round Table. The attendants are the general staff of a grand assault upon one tiny bastion of the unknown. All the facts they have learned so far and all the questions they have learned to ask finally simmer down each year to one formidable interrogation:

What is starch?

How are the atoms arranged in the starch molecule? Literally billions of pounds of carbohydrate raw material for industry are commercially available for industrial use, and yet no man on earth knows what it really is. Until the mystery of the molecular structure of starch is penetrated, no one can do more than guess at the huge flood of human benefits which may be released once that ultra-microscopic fact is determined.

The carbohydrate chemist, contemplating the enormous annual bulk of his constantly-renewable raw material, looks with admiration at what the hydrocarbon chemist has done with petroleum. The ring structure of the benzine molecule, when once understood, opened the way for a multitude of rearrangements of the hydrogen and carbon units, each undertaken with a degree of precise knowledge that made the result desired not only foreseeable but quite accurately determinable in advance. Fundamental knowledge of the molecular structure of the raw material enabled the hydrocarbon chemist to crack the crude oil and split the fractions into materials for an amazing series of industries. Fuels, medicines, solvents, insecticides, road materials, in astonishing variety, have flowed from that basic understanding of the benzine ring.

A score or more of able scientists, each from his own approach, are undertaking to find out how the starch molecule is put together. At the Massachusetts Institute of Technology the extraordinary powers of the electron microscope and the x-ray tube are being employed. At Ohio State University a scientist, employing special chemical tools of his own design, is pursuing the effort to discover more about the branch-chain structure of the molecule. Physical, chemical and genetic studies are being pushed at Iowa State College. Using a device called the ultra-centrifuge, a Columbia professor is seeking data on the size and shape of the molecule. Intensive studies into certain of the dextrins are the approach in the laboratories of the United States Public Health Service. Another Columbia professor is working with the effect of enzymes on the starch structure, and at Indiana University another man toils patiently in observation of the enzymic degradation or breakdown of starch. A man at Washington University in St. Louis is attempting to synthesize starch from sugar, and at the University of California another scientist is trying synthesis with other types of organisms.

These men and others are the leaders who gather for the Annual Starch Round Table. The expense is defrayed by the eleven companies which support the Corn Industries Research Foundation.

The Round Table was conceived and developed by dynamic Norman F. Kennedy, the Foundation's director of research, who hates to sit in the hard-bottomed straight chairs found in hotel ball rooms where scientific conventions are usually held. Noting that the best talk of the conventions usually was in the lobbies and parlor suites where others, like himself, appeared to prefer to slide down in well upholstered armchairs, he conceived the idea of bringing the carbohydrate experts together where they could talk to their complete contentment and in complete comfort.

The first two-day session at the Dearborn Inn in 1940 was not long enough. Since then four days have seemed too short for the talks, "sometimes quite fierce and bitter, but always impersonal and always intense." No prepared papers are read, no record is made except as individuals choose to make notes. Fundamental chemists scrape their theories against the practical difficulties of the industrial men, and the industrial men catch up with the latest ramifications of fundamental chemistry. Kennedy hopes shortly to bring to an International Round Table the leading European students of the subject. He wants "all workers throughout the world to learn a common scientific terminology, eliminate all confusions in concepts, to exchange ideas, results of research and, in general, to correlate all fundamental information in theoretical starch chemistry."

The learned knights of the Starch Round Table hurl their lances at an ultra-microscopic mystery which eventually they will conquer. The day when they can announce that the molecular facts of starch are fully understood will be the beginning of the end of grain surpluses. Without doubt it will be the commencement of a new series of industries offering new markets to farmers, new jobs for workers, and new products for the world public. Theirs will be a triumph in the spirit of chemurgy.

CHAPTER VI

Corncobs and Oat Hulls

I

THE most famous paragraph in the first great dictionary of the English language is the definition of oats. Taking a lexicographical side-swipe at the Scotch, whom he professed not to admire, Samuel Johnson wrote that oats were "A grain, which in England is generally given to horses, but in Scotland supports the people."

To which a Scotchman retorted: "That is why Scotland has such fine men and England such fine horses."

In America oats are fed to horses and also eaten by people. Even Dr. Johnson's vigorous imagination would have been too inadequate in his time to predict that in the America of our time oats also would be fed to airplanes, worn by motor vehicles, used to grind tools, and be listed among the innumerable substances which find their ways into plastics. The vocabulary in Dr. Johnson's comprehensive lexicon does not contain words to describe the scientific destiny of a modern crop of oats.

Johnson tossed no corncobs at the Scotch, for he probably had no idea what a corncob looked like. Some of the more urban readers of this book may be no more familiar with the appearance of the corncob, with its usefulness as a jug stopper, as kindling for the kitchen stove, or even as an excellent tobacco pipe. Having eaten corn-on-the-cob, the tasteless city-market degradation of fresh roasting ears, they may vaguely comprehend that a cob is the curious convenience upon which the grains of corn are arranged. There is the story of the little girls who passed back the cob with a polite request for "more beans on my stick." Since ripened ears of field corn are not carried on the subways, city people need not be chided as skyscraper yokels because the corncob is foreign to their experience. They may even be excused if they do not know that about 16,000,000 tons of corncobs are produced in the United States every year, most of which serve only the natural purpose of having the "beans" attached to them. Sixteen million tons of corncobs have for the most part been an agricultural nuisance.

Except for that super-delicacy, the morel mushroom, which Louis Bromfield, after eating his way around the world, rightly ranks well above pate-de-fois-gras, salmon trout or écrivisse; and except for a few salad greens, I can think of no plants of which the whole above-ground structure is eaten in its entirety. That is why agricultural residues and wastes are so interesting to the chemurgist. Their total tonnage is huge and all their components are potential chemical raw materials.

Nature goes to the trouble of erecting a stalk eight, ten or more feet into the air when she sets out to produce a handful of grains of corn. Near or below the middle of the stalk she shoots out the ear, and wraps it carefully in a tough husk. From the tip of the husk protrude the delicate silks to receive the pollen dropped from the tassel high above. Man has little commercial use for any part of this extensive structure except for the handful of grains which, within the husk, are arrayed in rows on the cob. The stalk, leaves, tassel, husk, silks and cob are largely ignored except as something to be disposed of, possessing a little value for feed or bedding. More than half of the corn crop is not grain, but a residue or waste which may be returned to the soil as an organic addition so poorly esteemed that no one offers a price for hauling it away. Soil experts now say that the stalks are worth six dollars an acre as fertilizer, so farmers doubtless have undervalued the fodder for that purpose. The cobs, from which the grain has to be shelled by a separate operation, are not even esteemed as fertilizer.

Likewise when nature goes into the oats business she grows a stalk or straw two to four feet high, and hangs a tablespoonful of oat grains in a handsomely ordered cluster at the very top of the straw. The grains when threshed hardly equal the weight of the straw upon which there is normally a price only in areas where livestock bedding is scarce. When the grain reaches a factory which intends to make oatmeal of it, the strong, strawy outer hull has to be removed before the kernel of the cereal is available to be rolled into breakfast food. The hulls are heavy enough to constitute about thirty per cent of the weight of the threshed oats.

Every such agricultural residue is a chemurgic challenge. Can a use be found where none has been known? Can a higher, more profitable use be found where present uses are partial or only barely profitable?

II

Oat hulls were long regarded as useful for only two purposes, neither of much value. Limited quantities could be sold when ground up and mixed in commercial livestock feeds to which they added a little fiber and bulk but virtually no nutritive quality; or they could be shoveled into factory furnaces, where at most their value was $1.50 to $2.00 a ton.

To the thrifty Scotch Stuarts who operate Quaker Oats, the largest company in the business, the idea occurred that oat hulls might be worth more for something else than for feed or fuel. They called in Carl S. Miner, a Chicago consulting chemist, who agreed to explore the problem. The first step in research always is to look into the scientific literature. Miner noticed that Department of Agriculture chemists had converted the pentosans in corncobs into furfural, and that oat hulls also contained pentosans, which are complex substances capable of being decomposed into certain forms of sugar.

No one at that time had any particular idea what, if anything, furfural was good for. One of thousands of laboratory curiosities, so little of it had ever been made that a pound cost $30 and fifty pounds would have been unobtainable because no one had ever wanted that much; and, of course, if there had been fifty pounds in existence a pound would not have been worth $30, for the same reason of supply and demand.

Nevertheless, since furfural appeared to be about the only probable item that could be made from oat hulls, Miner and his clients decided to make some. Perhaps if the stuff were plentiful enough to try, so that chemists could fool around with it, some cash-money use might turn up.

That was very early in the nineteen-twenties. By 1922 some sales were made. Twenty years later the demand for furfural became so tremendous that the supply of oat hulls was found to be insufficient.

Oat hulls got the furfural job in the first place for a simple but compelling economic reason: they were assembled in one place. At the Quaker Oats factory the quantities were so large as to be virtually a nuisance. They were there only because they had to be brought in before the machinery could get at them to unwrap the tasty kernels which were valuable in the breakfast food business. Farm residues usually are so widely dispersed, indeed literally so scattered in the fields that the cost of collection and transportation presents an economic hurdle more forbidding than any laboratory or manufacturing difficulty that may stand in the way of their utilization. No charge had to be levied against oat hulls for transportation. They were there.

The literature which Carl Miner had read plainly pointed out that more pentosans were in corncobs than in oat hulls. But the corncobs were not in Cedar Rapids where Quaker Oats was made. They were scattered all over the corn belt. Most of them never left the farms. No economic motive had appeared for trying to turn cobs into furfural; not enough of them were accumulated where they were in the way of any one person or company, nor even readily accessible.

Furfural is not classified among the nation's consumer goods. The product is not packaged for the kitchen cabinet, the medicine shelf, nor for any other form of direct use by the ultimate consumer. Entirely an industrial chemical, consumed by manufacturers in a score of processes, its identity disappears as completely from the view of the final buyer as that of the oat hulls and corncobs from which it is made.

"An amber-colored liquid that looks like tea and smells like almonds," according to the manufacturer's circular, furfural is an aldehyde. An aldehyde is a substance which is not quite an alcohol, having two fewer atoms of hydrogen in the molecule; neither is it quite an acid, but something in between. (Little of the huge vocabulary of chemistry can be translated clearly into layman's English, and if the reader understands from the foregoing exactly what an aldehyde is the explanation is quite as clear to him as it is to the author.)

After ten years during which furfural found an enlarging employment in industrial processes, primarily as a solvent, demand expanded notably when petroleum chemists applied it to the refinement of lubricating oils. Furfural, they discovered, was able to dissolve out those undesirable substances which were responsible for the formation of gums. While it took out the gums and the gum-forming substances, it left undisturbed the properties which the oils should retain. A dozen petroleum manufacturers eventually adopted the oat-hull product. Thus it is that oats are fed to airplanes for the perfection of their lubrication, and to motor vehicles for the same purpose. Oil became furfural's largest consumer.

This curious substance has versatile qualities which have put it on the payrolls of other industries besides petroleum. Oats in the raw state obviously would be worthless as material for grinding hard metals. Furfural, however, has become highly essential in the making of modern abrasives. The old grindstone, so ardently hated by every farm boy assigned to turn its crank while his father ground a six-foot mowing machine knife, is going the way of the sickle and the cradle. The high-speed grinding wheel sharpens the tools of industry and has become the instrument for shaping and machining metals. Such a wheel is built up of millions of tiny particles of exceeding hardness, astoundingly cemented together by synthetic resins that resist heat and water and must themselves be tough and hard. Furfural does so good a job at contributing to these factors that makers of nearly all modern grinding tools look to the fields for oats as one of their ingredients.

The behavior of furfural when teamed with carbolic acid has made the two substances an essential pair in the making of synthetic resin plastics. Thus it comes about that steering wheels and helmets, electric insulating boxes and various other plastic materials in war and peace depend heavily upon the "amber-colored liquid that looks like tea and smells like almonds."

The future may find furfural specified as a highway material. The substance has a curious characteristic which has suggested this possibility. When a bituminous-surfaced road is constructed the durability of the surface and the cost of its maintenance are materially affected by the degree of adhesiveness with which the tar sticks to the stones and by how well the entire surface hangs together. Given a good sprinkle-bath of furfural, such as might cost an extra two hundred dollars a mile, a small sum in proportion to the cost of a good road, the bituminous material appears to grab the stone with extraordinary firmness. Experiments in Missouri are reported as "inconclusive," so that no positive prediction can yet be made that oats are destined for highways. The quantities which might be consumed, if this use became general, are fabulous.

While no one should look between these covers for text book procedures in practical chemistry, a crude, non-technical account of the process by which a bushel of oats gives off less than a pint of furfural (1 bu. oats (32 lbs.) = 6.6 lbs. hulls = 0.79 lbs. furfural, or 2/3 pt.) may serve to illustrate a representative process by which the organic chemist transforms a farm-grown raw material into a product with widespread industrial markets.

After being ground, the oat hulls are fed into a digester. They are moistened by a 5 per cent sulfuric acid solution under steam pressure of 60 pounds per square inch at a temperature of 153 degrees Centigrade. The digester revolves, and projections inside keep the mass of oat hulls stirred. The piping arrangements permit the steam to be drawn off from above the mass of hulls. After passing through a drum where remaining hulls drop out, the steam feeds into a fractionating column, an upright copper vessel containing a series of plates so arranged that, as the steam cools, the water and the furfural can be drawn off separately. This is a highly simplified account of a technical and exact process, but will convey some idea of the operation.

III

Commercial production of furfural quickly took the compound out of the $30-a-pound laboratory curiosity class. The first of the output was sold in drums in January, 1922. The buyers paid 50 cents a pound. Before the leaves had fallen the price was down to 25 cents a pound. By 1926 it was 15 cents a pound and instead of in drums, furfural was leaving Cedar Rapids in 60,000-pound tank-car lots, although even then not many tank cars were required to transport the total volume. One of the uses which had been found by that time was in the preparation of germicides and fungicides to dress tree wounds. That market probably was sought after some one found that furfural penetrates wood so thoroughly that a wooden container will not hold it and that when exposed to air or light it eventually resinifies itself. Some was sold to flavor tobacco, some as a solvent in shoe dyes and leather dressings, and some as an ingredient in fly-repellents.

The declining price figures for many years had only a little relation to costs and none to profits. Prices were set to produce volume consumption, in the hope that with volume profits eventually would come. Furfural was no chemical miracle. More than once the research chiefs as well as the business office wondered whether they would ever have started the effort had they been able to foresee the cost in money and toil and disappointments. Probably a million dollars in money and immeasurable courage and patience was expended before black figures emerged at the bottoms of the accounting columns.

The war-time price was 9½¢ a pound, a long way down from the $30 of less than a quarter-century before. The manufacturers' goal is to shave the price still more as time goes on. They believe that whole new markets will then demand their aldehyde, a belief that no doubt is based on very definite factors in chemical economy.

This splendid expansion of furfural production from nothing to many annual millions of pounds, while the price has been lowered to less than one-fifth of the first commercial figure, exemplifies several aspects of chemurgy's fundamental philosophy. A waste, virtually worthless, has found highly useful employment. The product, something never before available, has in the main displaced no previously existing material and has contributed new and valuable services toward providing superior materials and equipment for the nation's work. New jobs have been made, new wealth created, and in consequence improved elements have been supplied to the standard of living.

The instance would be more nearly perfect if to all this could be added some evidence that the new value attained by the by-product had been enough to increase the price to farmers who produce the oats. This does not seem to be the fact. After all, large as is the business of the one company which makes furfural from oat hulls, the entire annual purchases of oats for breakfast food are small in proportion to the total production and to the total consumption as animal feed, which in America, as it was in Dr. Johnson's England, is the major market for this grain. The portion of the oats crop purchased for conversion into human food does not swing the market. A bushel of oats yields .79 pound of furfural which, at 9½ cents a pound, is worth 7½ cents. Therefore it would be hard to prove that a use for the limited quantity of hulls removed for the breakfast food process, important and interesting as it may be, has improved the price of oats for farmers. The next part of the story, however, can report some direct return to farmers.

IV

After struggling for two decades to create enough markets for furfural to consume their supply of oat hulls, the manufacturers were suddenly confronted with a demand that exceeded the oat hull supply. War required lubricants in extravagant quantities, high octane gasolines, and an enormous volume of a new product, butadiene for synthetic rubber.

The butadiene need was immediate, urgent, and immense. The furfural requirements were so far in excess of pre-war output that a new, government-built plant was hurriedly erected at Memphis, Tenn., where it opened in July, 1943. Operation was assigned to the Quaker Oats Company, then and still the only producers of furfural.

The South's cottonseed hulls and rice hulls were tried as raw materials. Both contain pentosans, and experimental data had led to the expectation that either would be suitable. Probably for this reason the plant was located at Memphis. But the rice hulls yielded only about half as much furfural as oat hulls, and the cottonseed hulls had been consumed almost entirely in certain stock feeds during the war. So the order went out for corncobs, as research by the Department of Agriculture, long years before, had revealed that corncobs were one of the best sources of furfural.

The cobs were still badly scattered, but not quite so thoroughly dispersed as they had been twenty years earlier. A new factor had entered the picture. The hybrid corn industry had come into being, and had grown to be fairly large. No longer did every farmer carefully and laboriously shell his own few bushels of choice ears for seed. Seed corn was produced on special farms under controlled handling and, when harvested, was shipped to central points for drying and shelling. Larger concentrations of cobs were to be found, although not in quantities large enough to supply all the new needs. Cobs also are accumulated at grain elevators, where ear corn is delivered by farmers and shelled by the handlers before being loaded for shipment.

From ten to fourteen pounds of cobs are grown with each bushel of corn. They are comparatively light and bulky. A bushel of cobs weighs about 15 pounds, a bushel of crushed cobs about 19 pounds, and when ground to a meal about 30 pounds. Not only is the cost of their collection a limiting factor in their commercial use, but so is the transportation of so awkward a product. Most of the cobs shipped to the furfural plants are ground in portable hammermills and blown into box cars. Unloading was promptly found to be a problem. They wouldn't flow freely, as does grain. An exasperated mill manager proclaimed that the particles "hang together like a bunch of fish hooks." Speed of unloading was more than doubled by use of a suction system, although that, too, proved slower than desired.

Single-operation machines to grind the cobs and press them into pellets are being developed with the hope of improving the efficiency and lowering the cost of transportation. A Chicago engineering firm is reported to have set up two plants, each capable of handling 10,000 tons of cobs a year, with processes which dry and pulverize the cobs, blow the chaff and pith back to the furnace, and package the hard, woody parts for shipment.

Returns to farmers who supply cobs are not large, but some cash gets to the farm, especially where the portable mills are in operation. Since cobs have so long been a nuisance at elevators, in a good many instances they have been given away for the sake of their disposal. Men in the business of collecting cobs for furfural have been paid $6 to $7 a ton for the ground cobs blown into freight cars. Farmers have been paid $1.50 to $2.00. A farmer with a corn yield of 60 bushels per acre would have upwards of 600 pounds of cobs from an acre. If he received only 50 cents for the 600 pounds, he would have $50 from 100 acres; most commercial corn growers in Iowa, Illinois and Indiana, where cob collection is concentrated, are likely to have 100 acres or more each year in corn. Small though the cob revenue may be, nevertheless it has to be reckoned as a definite gain from a product which has been not merely a waste but usually a nuisance.

Furfural has been by far the largest war customer for corn cobs, but not the only one. They have another war job; important though of much smaller dimensions. Ground cobs, small enough to pass through a 10-mesh screen and large enough to be retained on a 32-mesh screen, will remove organic matter and deposits caused by oil, dust, carbon and rust, from engine parts, bearings, and other metals which have to be cleaned carefully without injury to delicate surfaces. The cobs are blown through ordinary sandblasting machines with ³⁄₁₆-inch openings. For the U.S. Navy cobs have been chosen as the standard material for such purposes, while shell cases and other army ordnance products have received the same treatment.

For two or three decades ground cobs have been sold for use in sweeping compounds, for metal burnishing, and for cleaning furs. They have been mixed in ceramic clay for lightweight tile. Empty air spaces remain after the clay is burned.

A substantial backlog of research notes relating to the chemical properties of corncobs has been stored up. The cellulose, lignin and hemicellulose in sixteen million tons of corncobs is an immense store of potential wealth, once man figures out how to accomplish the transformations and evolves means to assemble large accumulations cheaply enough. Nine-tenths of America's three-billion-bushel corn crop is never moved from the counties in which it is grown and harvested. The relatively small fraction that feeds factories instead of animals sustains a number of great industries. One may hardly anticipate that cobs will ever become so desired that all the huge tonnage will acquire commercial value. A steadily larger proportion of those that grow on the richer corn lands of the mid-cornbelt states may eventually do so, though the sawdust and wood waste piles, also ready sources of lignin and low-grade cellulose, may have to be used up first. However, some one has pointed out that twenty years or more are generally needed to grow a tree to marketable size, while corncobs with substantially the same chemical values can be harvested every autumn.

Meanwhile, along the Big Muddy in Missouri, around Boonville and Washington, a special variety of corn is grown for the sake of the cobs. The grain is secondary to the thick, compact, uniform cobs to which it is attached. These cobs are a million-dollar-a-year business. They are made into corncob pipes.

CHAPTER VII

Soybeans, a New Crop that Has Arrived

I

A JAPANESE bomb made a pretty fair hit. The enemy had roared in against the American fleet at the Marshall Islands. The great aircraft carrier *Enterprise* was the bomber's victim. The crash and confusion of the hit and the horror of young deaths were instantly heightened when the flight and hangar decks burst into full blaze. Leaping and exploding flames of high-test gasoline threatened to finish the ship with mounting tragedy to fine young American lives.

Soybeans were ready for that emergency. In the hands of the ship's fire-fighting crews, they extinguished the fires in almost exactly sixty seconds.

An exacting and costly process of chemical research and manufacture stood behind that extraordinary event, and no little agricultural history, too.

The phenomenal rise of the soybean, which within a quarter of a century came from a little-known plant experiment to its present position of a foremost cornland crop and a product with myriad uses, is accounted for by two major factors. One is that soybeans fitted well into American agriculture. The other is that research vigorously and promptly explored the hidden values of the amazing bean.

The late Russell G. East, lamented by thousands of friends, once remarked that farmers couldn't very well lose with soybeans. The crop was good for pasture. Hogs and cattle and sheep liked the whole green bean plant in the field. It made nutritious hay, or could be put in the silo. When properly handled the crop is good for the soil. An active market, either for seed or industry, always awaited the harvested beans.

It was Mr. East who, as general agricultural agent of the Pennsylvania Railroad, conceived and executed in the late thirties an educational dramatization of soybean progress. He persuaded the railroad to build and exhibit over its lines a soybean exhibit car. The car ran on wheels which were cast with the aid of soy protein and oil used in the foundry cores. Inside and out, "from rails to roof," it was adorned with paint and varnish made from soybean oil. The interior finish was plywood put together with soybean glue. The car was filled with materials manufactured from the soybean. Exhibits included foods, paints, wallpaper, soap, flyspray, automobile parts, linoleum, explosives and livestock feeds, among other soybean products. The car paid off, incidentally, by stimulating farmers' desire to produce the crop. In subsequent years the railroad hauled more soybeans as freight and took more goods back to the farm towns to be sold for soybean money. Other railroads borrowed the car for display later on their own lines. During 17,643 miles of travel through eighteen states 198,286 people inspected the exhibits.

Promotion was able to advance the soybean, however, only because of a fundamental fact. The United States has never produced as much protein as the people want, nor as much vegetable oil. Neither, for that matter, has the rest of the world. The soybean is an efficient, fruitful source of both of these basic commodities.

II

No adjective has more frequently nor more accurately been applied to the soybean than *versatile*. The flexibility of agricultural application has been mentioned. Industrially the soy is a one-bean band with an almost bewildering variety of uses. Whitney H. Eastman, president of the Vegetable Oil and Protein Division of General Mills, Inc., in 1944 remarked that General Mills research laboratories had counted one hundred and eighty-one soybean products; "all of which," he added, "might have numerous variations as to type and properties." The list by now would probably be an out-dated underestimate.

Overenthusiastic expectations regularly lead those best acquainted with the crop and its products to point out that soybeans can't do everything, and that is true. The usefulness of "the little Oriental wonder bean" nevertheless extends into so many avenues of human service that overestimating its future remotely resembles overestimating the significance of atomic power.

The physical and chemical properties of the soybean account for its astonishing versatility. Wrapped within the tight and thin outer covering is an extraordinary combination of protein, fat, carbohydrates, vitamins, enzymes, minerals and phospholipids. Relatively speaking, these various components are easy to lift out and separate. Nature almost outdid herself when she created a vegetable product so conveniently and bountifully supplied with ingredients of useful character. One by one and two by two these ingredients have been lifted out, combined with other materials, and set to work for better human living.

First brought to the United States from China about 1804, the soybean was an accidental child of circumstance. The story is that a Yankee skipper, doubtful whether his food supplies were adequate for the long voyage home around the southern capes, tossed a few bags of soybeans into the ship's hold. Doubtless he reasoned that since the Chinese ate the things and thrived, the beans would in an emergency sustain life for his sailors. Actually they probably would have afforded a better balanced diet than whatever he had on board. In any event, all or part of the supply remained when he tied up in the home port, thus providing the original soybean seed supply for America.

For more than a century soys were grown as a sort of curiosity in occasional gardens. Little was known about their honorable and ancient history as recorded by Oriental scribes back as far as 2800 B.C., nor of the numerous and important values which the Asiatics had found in the bean.

The twentieth century was fairly under way when a few farmers began to plant soybeans for hay; others mixed them with their seed corn to add protein to the maize carbohydrates when the fields were hogged down by self-propelled porcine harvesters. Profitable, these practices created a demand for seed. Despite the expensive and difficult operations of cutting the mature crop with a grain binder and putting the bundles through a threshing machine, enough seed was supplied to meet most of the expanding demand.

The combine-harvester, which cuts, threshes, and bags or empties into a truck as it goes, slashed the production costs and enormously increased the potential of the crop. Long before this, as early as 1911, the first soybeans were processed in the United States. This was at Seattle and the soybeans were imported from Manchuria. I. Clark Bradley just after World War I managed a plant at Chicago Heights, Ill., and began a long pioneering career as an industrial exponent of the soybean. A. E. Staley, another pioneer, started buying and processing soybeans at Decatur, Ill., in 1922, and in 1924

Eugene D. Funk, famous seedsman, opened a processing plant at Bloomington, Ill.

Private enterprise carried through in 1928 the step that moved the crop toward its big advance in the corn belt. H. G. Atwood, a prominent feed miller; Eugene Funk; and men of the Grange-League-Federation, the latter a large New York State cooperative handling livestock feeds, met together. They announced that they would contract to buy all the soybeans produced that year on 50,000 acres, at a price per bushel determined in advance of planting. This program was continued until momentum was fairly well established in the several segments of the industry. The 1928 crop was 7,880,000 bushels; in 1929, 9,000,000. Within less than a decade and a half more than 200,000,000 bushels were grown in a year.

III

About one-fifth of the soybean is oil. The first step in processing is to extract that oil, every drop of which is useful. There are quite a number of drops, since of late more than twenty thousand tank cars of the oil have been produced annually.

The oil is itself a substance both complex and accommodating. Merely to mention a few of the larger uses: you can eat it; you can eat it as a shortening in your pastry or spread it on your bread as margarine; you can put it on your salad in an oil or in mayonnaise or other dressing; you can cook with it. These, in fact, are presently by far the major uses, since more than four-fifths of soy oil production is consumed as food. According to Edward J. Dies, Chairman of the National Soybean Processors Association, in his informative, authoritative and readable book, *Soybeans, Gold from the Soil*, the 1939 uses were 54.5 per cent for shortening, 19.2 per cent for margarine, and 8.8 per cent for salad oil. The rest was consumed for industrial non-food purposes.

The critical war need for oils and fats led to severe restrictions upon non-food uses of soybean and other vegetable oils, and likely deferred many technical applications. However, a few of the end products in which a consumer is likely to encounter soybean oil, or in the manufacturing of which it was used, are listed by Whitney Eastman as "paint, lacquer, enamel, resins, putty, caulking compounds, oilcloth, linoleum, shade cloth, oiled clothing, leather, wallboard, core oils, oiled parchment, sulphonated oils, lubricating greases, printing ink, disinfectants, insecticides, tin plate and terne plate, soap and waterproof cement."

Marvelous as is the soybean, it falls far short of doing all these things by itself. Long, expensive, painstaking chemical researches lie behind many of these adaptations. Upstanding, bare-handed selling has also had a determining part. Vegetable oils are, to a remarkable degree, interchangeable. The shortening maker or the margarine manufacturer splits not only pennies but mills, and splits them finely, when he figures the costs of his raw materials. Soy oil is his choice only when cost, quality and other factors give him good reasons to prefer it. Being the Johnny-come-lately among vegetable oils, it has always had to nudge a competitor aside before closing with a buyer. By 1945 the annual volume of soy oil had exceeded that of cottonseed oil, which had long been the leader.

Constant improvements have been made in refining processes and in attaining modifications which improve its attractiveness for each particular purpose. Processors labor assiduously to make soy oil not only attractive but superior and, if possible, indispensable. From the competition the public benefits through better consumer goods at lower prices.

The fractionation process in petroleum is well-known.

Crude oils are separated by distillation into fractions, each of which may be designed for its own specific purpose.

Applying the same basic principles of fractional distillation that are used to separate crude petroleum into products for higher uses, Armour and Company and others have applied fractional distillation to soybean oil. The oil is first split to separate it into glycerin and fatty acids. The mixed fatty acids are then passed through a continuous high-vacuum fractionating still which partially resolves the mixture into its individual components. The saturated palmitic acid fraction is marketed for such purposes as soap, cosmetics and rubber. The unsaturated portion emerges as a high-quality drying oil component for use in paint, varnish or lacquer, manufactured by the protective coating industries. Each of the separated parts is better for its purpose than the original soybean oil.

Quoting Mr. Eastman again, since a few technical words are necessary, "Fatty acids of soybean oil have some very unusual and useful properties. By splitting off the glycerines the acids find a wide and expanding use in alkyd resins, synthetic rubber, resynthesized glycerides and a long list of chemical compounds and derivatives. A new series of soybean oil derivates has just (1944) recently emerged from the research laboratories of General Mills. They are in the form of alcohol-soluble resins used for protective coatings and heat sealing adhesives."

If there is any doubt about the technical character of the long new reaches in soybean research, note the language of Mr. Eastman's concluding sentence, keeping in mind that each syllable has a definite meaning in the language of organic chemistry, and, indeed, may almost indicate a separate process, reaction or compound: "Chemically the products are known as the ethylene diamine polymide of dimerized and trimerized linoleic and linolenic acids of soybean oil."

Linseed oil, the fat of flaxseed, has long been the preeminent oil ingredient as a vehicle in paint. Soybean oil has chosen to challenge the impregnability of that position.

The drying quality of glyceride oils is measured by the iodine number, an abstract measurement of the oxygen absorption of an oil. Curiously enough, if I am informed correctly, the iodine number actually has nothing to do with the drying quality but by some natural coincidence does serve as a fairly good indication.

Soybean oil is a so-called semi-drying oil. For that reason commercial paint manufacturers resisted its use, even in paints that did not need to dry in any particular hurry. The development of better oil-bearing varieties and improved methods of processing and refining all had their part in diminishing this resistance. Soybean oil paint forced its way ahead several steps after the powerful Illinois Agricultural Association decided not to wait on the old established paintmakers. By cooperative arrangement these Illinois farmers had paint made containing oil from their own soybeans and sold it among themselves.

Protective coating manufacturers, however, were not really ignoring soybean oil. Their chemists were working with it. As M. F. Taggart, of the O'Brien Paint and Varnish Company has said, "Progressive paint chemists now know how to make your oils sit up on their hind legs and wiggle their ears."

War demands largely excluded soybean oil from paints because it was needed more for food. However, in 1941 paint and varnish consumption of the oil was 41,594,000 pounds, fourth in volume of use only to shortening, margarine, and all other edible products. This consumption will rapidly expand because Taggart and other "progressive paint chemists" and research workers have established the oil in the field, and because fractionating processes will provide a superior raw material. One of Taggart's paints required 45 per cent of soybean oil.

A rapidly expanding field for soybean oil is in alkyd resins. Some leading technologists in the paint industry predict that the use of soybean oil in alkyd resins will greatly increase. This is because new and more plentiful solvents appeared during the war, and because the soybean-oil alkyd-resin varnishes and lacquers exhibit a markedly superior resistance to the yellowing action of sunlight.

"The stimulus of war," says Dr. O. E. May, former Chief of the Bureau of Agricultural and Industrial Chemistry, "has fostered new developments in the art of modifying soybean oil to impart fast-drying properties. The mechanisms involved in effecting structural rearrangements which result in more rapid polymerization are now much better understood than they were a few years ago, and the application of our newer conceptions of this phase of oil chemistry may result in far-reaching changes in the field of protective coatings."

IV

The chemical that put out the fire on the carrier *Enterprise* in one minute was fire-foam. The basis of fire-foam is alpha protein, pure protein isolated from the other ingredients of soybean meal. Fire-foam, sprayed under a pressure of 125 pounds per square inch through specially-nozzled hose which mixes 94% of fresh or salt water with 6% of the compound, literally blankets flame with tough, gas-tight bubbles six to eight inches deep. Oxygen is excluded. Gases are sealed in. The fire, having nothing to feed itself on, immediately subsides. The foamy blanket adheres so closely that a high wind will not blow it free. A blow-torch can be run over the foamy blanket without igniting a highly-combustible product underneath.

For the duration of the war the Navy purchased the entire output of fire-foam. The product is, however, now available for general purchase as a fire-fighting agent. Other uses of soybean protein are in prospect, one of them being to carry spray materials so that they will stick tight to trees and plants and reduce the quantity of toxic material required for insect control.

Alpha-protein, isolated in pure form, is the product of nine years' difficult and costly research by the Glidden Company. The investment in the process was so large that only a high and continued volume of output and sales will offset it. Only a part of its market is exclusive; much is competitive with other materials. A number of the large industries, such as paper, paint and other coatings, textiles, linoleum, leather and rubber are included in the potential market.

As though to verify the versatility of the soybean, another of its products, lecithin, acts as an anti-foaming agent, in contrast to the foam-making property of aplha-protein. Such agents are required in industrial processes where the formation of foam interferes with the prompt movement of liquids or with desired reactions within solutions.

Once made only, in small quantities, in Hamburg, from the yolks of eggs, lecithin has become an industrial compound with many functions. You may find it in your automobile tank as a stabilizer for ethyl gasoline and also as an ingredient of the chocolate coating on the candy you munch while looking for a better roadside eating place than those you have passed. Originally the principal application was to encourage the emulsification of oils and fats. Blended with creosote, lecithin prevents the "bleeding" of preserved wood. It is a wetting agent. Such diverse products as cosmetics and insecticides, munitions and pastries, pharmaceuticals and paints, pottery and printing inks, powdered metals and rubber, lubricants and ice cream, are consumers of lecithin.

V

The rear of Seattle's old Grand Opera house, back around 1908, was the scene of the real origin of industrial uses for soybeans. There a 26-year-old Ohio-born chemist, Irving Fink Laucks, operated a laboratory which performed custom chemical analyses. His clientele kept his force busy as beavers part of the time, but not all of the time. He looked around for a promising problem that would keep the staff interested and that, if answered, might develop into a business.

The Northwest's nascent plywood industry, based on huge forests of Douglas fir, provided the problem. The wood was abundantly available and the mills knew how to slice it thin. The fragile pieces of veneer needed glue. Manufacturers of starch and animal glues were able to supply glue but by the very nature of their products nothing could make it stick when exposed to moisture. These readily-available adhesives were not water-resistant, and that fact put definite limits upon expansion of the markets for plywood.

Laucks surveyed the situation and surveyed all the existing adhesive raw materials. He discarded one after another, always coming back to and finally settling on soybeans as the material. That was well before soybean production had become more than noticeable anywhere in the United States. Having been called upon for analyses of it, Laucks knew that Manchurian soybean meal in small quantities was arriving in Seattle for sale as livestock feed. He began buying the big cartwheels of soybean cake which arrived shaped as it emerged from the Manchurian animal-power oil presses. He tried grinding them to a flour, and making them into glue. No two batches were very much alike until he learned to choose cartwheels of suitable quality. Then came the difficult job of getting a plywood maker to adopt his product. Their equipment was not adapted to spreading this kind of glue. Even after trials had finally gained a customer or two, more were hard to persuade. Buyers would apply the traditional tackiness test. With a bit of wet glue in the palm of one hand they would pat it with the fingers of the other. If sticky strings began to adhere to their fingers, they figured a good glue was being offered. Laucks' soybean glue had a notable peculiarity; it was not tacky. The mill men called it bean soup and waved it away. Expansion was also restricted by the fact that so few plywood mills knew how to use the soybean glue that Laucks usually had to post his own men to assist in the operation.

"Probably this was a good thing for us," he said long afterward. "It kept us from making too many mistakes too far from home."

Automobile makers began to buy plywood for floor boards, instrument boards and later for running boards. The plywood industry fell into a fair-sized furor when many of the running boards fell off. They were not water-resistant enough.

The industry united for the first time, and appointed a committee to choose, after exacting and exhaustive tests, a glue that would meet the automobile demands. They agreed in advance that all would install whatever equipment was necessary to use the glue agreed upon in order to maintain acceptance of all plywood from the industry.

The period of the tests, in 1926, was a breathless time for Laucks and his organization. They were in line to get either all the business or none of it. By the end of 1927 they had all of it on the Pacific Coast.

That called for more soybeans. Laucks came to see Eugene Funk in Illinois and shortly began his career as a substantial consumer of home-grown soybean oil meal. He took on eastern plywood box-shook makers as additional customers.

Later Laucks set out to adapt his soybean glue to the large existing market for adhesives which tie sizing materials such as clay and whiting to highly-finished papers. That project failed because the characteristics of the glue base were not suitable for the purpose. The whole approach was laid on the shelf while another attack was undertaken. Later with what was put on the shelf Laucks and his men developed the first washable wallpaper and has held on to virtually all of that market.

Never abating in his persistent research with plywood problems, Laucks eventually came up with a process, growing out of his experience with synthetic resins, that used soybean glue to make a plywood not only water-resistant but waterproof. So now the industry is having to change equipment again in order to install hotpress machinery, necessary for the new method, to replace the coldpresses. Since they had become accustomed to shipping a billion square feet of plywood a year even before the war, they do not so much mind this change.

Chemist Laucks expanded his once-small laboratory into soybean glue plants at Seattle, at Portsmouth, Virginia, in Vancouver and Stockholm, in addition to successes in other chemical fields. He has reason to speak highly of soybeans. The authority of personal experience stands behind him when he asserts firmly that "if steady systematic research is conducted on farm products, continuing new uses will be found and wider markets assured to farmers."

VI

No doubt children are still asked to explain the wonderful fact that a red cow after eating green grass will give white milk that can be made into yellow buttter and blue cheese. A good many profoundly learned chemists would like to hear an authoritative explanation of that. Some of them might offer in return their own version of another wonder.

Here is a field of soybeans. Sheep flourish on soybeans as pasture or hay. Sheep grow wool, from which a suit of clothes can be made.

Cows also do well on soybean pasture, hay, or silage, and enjoy the protein concentrates made from soybean-oil meal. They will give lots of milk from which, after a generous quantity of food values has been removed, whey is left. From the whey casein is made and from the casein a protein fiber, very similar to wool, can be processed. A tailor can take a fabric made with the casein fiber and fashion an excellent and handsome suit of clothes. The cow, so to speak, has been persuaded to give wool.

Given the protein from the soybean, a chemist associating with no sheep or cow can produce a pure soybean protein fiber which also can be fabricated into a suit of clothes. And why, he will ask, should one bother with weepy-eyed sheep or mooing cows when an acre of soybeans without them will yield more square yards of cloth than can be sheared from the sheep who have always monopolized the wool business?

The answer may be that it depends somewhat on whether it costs a sheep or a chemical manufacturer more to produce the fiber, and which fiber consumers will choose.

Working first with Henry Ford at Dearborn and later with the Drackett Company of Cincinnati, a youthful chemist named Robert Boyer has been the creator of soybean fiber. This is strictly a man-made fiber; the soybean contains no large amount of fibrous material as does a cotton boll or a hemp stalk. First the protein has to be isolated from the rest of the bean. The sticky substance is subjected to the presence of a suitable solution of chemicals, squirted through spinnerettes into a bath which fixes the fiber and is then wound up to be formed into skeins. Mildly lustrous, loose and fluffy, light tan to white in color, it feels soft and warm, has a natural crimp, and is highly resilient. About three-fourths as strong as wool, moisture considerably lowers its tensile strength but otherwise affects it little. Blended roughly half-and-half with wool, or even with less wool, the soybean fiber is said to make admirable upholstery fabrics and blankets and to be suitable for other uses. No announcement has been heard, as this is written, of commercial production.

Back in the laboratories also is a transparent wrapping material or film produced from soybean protein. There are hints that it may become a competitor in that field.

VII

Contrary to popular impression, soybeans are not extensively used in molded plastics. Experimentation has developed large numbers of such possibilities. Soybean protein lends itself to several forms of use in plastics. In combination with other chemicals it has been found adaptable to numerous requirements. Large numbers of plastic objects containing soybean protein have been made and exhibited.

So far, however, the actual consumption of soybeans in plastics has been an extremely small fraction as compared either to total soybean oil meal production or the total production of plastics. This may be accounted for by the fact that higher uses for soybeans have appeared, or that other materials have proven more satisfactory and economical.

VIII

The industrial utilizations of the soybean have been so dramatic, and the further potentialities appear so extensive, that they command interest and attention sufficient to distort the conception of their actual proportions.

More than four-fifths of the oil, it already has been pointed out, is consumed as human food. No more than twenty per cent has in any recent year been purchased for non-food purposes. In the earlier years, however, before the food values were so well appreciated, the industrial uses were more than half.

While their individual stories are infinitely more fascinating, the non-food uses of soybean meal so far have probably not exceeded five per cent of the total production. Some ninety-five per cent plods along at the highly useful though more prosaic task of providing nutritious protein ingredients for the feed of the animals and fowls which in turn supply the American table with the richest and most varied abundance of meat and milk and eggs enjoyed by any people in the world.

Nevertheless the chemurgic uses of the oil and protein of the soybean have been a continuing and stabilizing factor in the history of the crop. The percentage of both the oil and protein used for industrial purposes has been high enough to tip the balance upward in the scales of price and to create a decisive factor in demand. Those new uses which will emerge as the unremitting curiosity of research carries on will add new elements to the American standard of living, create new jobs, and strengthen the stability of the agricultural base of our national economy.

Expanded acceptance of soybean products in the American diet is to be expected and welcomed. The production of soy flour has risen to a level that has called for organization of the Soy Flour Association. The secretary, E. L. Rhoades, speaking before a chemurgic conference in 1942, said:

> The food manufacturers of the United States have quietly been adding during the past year small percentages of concentrated soybean protein in the form of soy flour or otherwise, to a large variety of foods. Their primary purpose has been to use this protein to supplement and activate the incomplete proteins, such as cereal proteins, without substantially changing the identity of the food,

> but merely with some improvement in palatability, flavor, and texture. It has been difficult during the past year for anyone normally purchasing doughnuts, bread, pies and other bakery products, soups, meat loaf, candy, and many other prepared foods, to avoid consuming some soybean protein to their own nutritional advantage. In this development, the tonnage so consumed has probably been vastly overestimated, while the number of people consuming this food and the nutritional benefits derived from it have probably been vastly underestimated . . .
>
> Looking into the future, we see soybean protein performing three basic functions: (1) adding a nutritional protein plus to a national diet that has not always been adequate in quantity or quality of proteins: (2) providing a flexible protein supply that will insure adequate protein nutrition in any type of emergency, and (3) providing an exportable protein for the American farmer . . .
>
> The American public could well use an additional 5 grams or even 10 grams of soy protein per day to promote maximum health and vitality.

Numerous edible varieties of soybeans have become sufficiently popular to be listed in seed catalogs. Canning companies have been packing the edible soybeans, which are distinguished from their brothers in the grain fields by containing no unpalatable ingredients. Their flavor, in fact, is among the best of bean flavors, while their protein content almost justifies the claim that they are an equivalent to meat.

IX

The rise of the soybean from obscurity to high fame has not been accidental but laborious. Hundreds of men and scores of corporations could be named on the honor roll of soybean progress. Nature filled the soybean with the elements of riches; man has had to toil and think, to plan and risk, to create and sell before those riches could be laid at the feet of humankind in the service of progress. Aid was extended from many hands to achieve the soy's swift ascent to its present eminence as the foremost oilseed and the foremost vegetable protein in the nation.

First in the field were a few far-seeing enthusiasts in the U.S. Department of Agriculture who were convinced by reason and perhaps by hunches that here was a plant species with a great American future. They, more than most others, knew something of its extensive uses in the Orient; they knew that high food and feed values existed; even primitive chemical analyses may have suggested a few of the industrial values, most of which, however, could not have been foreseen. Among these enthusiasts was one young man who, inspired by what he believed, never let go of his dreams for the greatness of the soybean. Patiently he searched the markets of the Orient and sent ten thousand samples home for trial as possible new varieties. He has lived to see two hundred million bushels grown to enrich the people whose faithful servant he has been. His name? You can't find it in Who's Who. It's William J. Morse.

Then came the pioneer farmers in North Carolina, Indiana, Illinois and Ohio, who saw agricultural merit in the soybean. They risked their effort on trying varieties, experimented with the products as feed, slowly learned the practical methods for adapting the crop to the necessary routine of the farming season. A scant dozen or so of such farmers were among the foremost. From their farms came the seed beans to multiply the acreage when the demand began to surge upward.

Alongside the farmers were fewer than a score of men at the state experiment stations, faithful scientists who patiently seeded small plots, painstakingly compared variety with variety, and scrupulously measured the results. Among these, too, were geneticists skilled in matching the strength of one variety with the merit of another to evolve offspring superior to both. The rise in average per-acre yield from eleven bushels in 1924 to more than twenty bushels fifteen years later reflects largely the patient expertness of these agricultural scientists.

The public scientists had their salaries. The farmers could live by growing other crops. Bigger risks were taken by the industrialists who, to create the processing facilities for the crops to come, had to risk substantial investments in machinery and sales costs. More than one had his periods of doubt as to his own wisdom. Courage and persistence with a multitude of minute details preceded the later days when soybean processing and manufacture grew to become a big business.

Twenty-five years of American freedom enabled the soybean to accomplish infinitely more than its previous three thousand years under Oriental despotisms and chaos.

X

Hoping that one who quotes from his own works will not be regarded as more than moderately immodest, I conclude these episodes from the saga of the soybean with a few thoughts once expressed elsewhere. The following paragraphs are from an address presented before the twenty-fifth annual convention of the American Soybean Association at Urbana, Illinois, in 1944:

> I should like, if I were able, to calculate the benefits which have been created for the United States of America by this interesting achievement in production. It would not be too difficult to multiply the annual crop by the average price of each year, and thereby obtain an approximate total of the dollars the soybean has earned for its producers.
>
> That figure, however, would be grossly insufficient. The soybean does not stop its constructive course when it is sold from the farm. These hundreds of millions of bushels have made an enormous number of jobs for men who needed them. During the depression years, from 1930 to 1941, while the demand and pro-

duction of soybeans were rising steadily year by year, each one of those extra jobs was tremendously important to some family. There were jobs hauling the beans, jobs in the elevators and on the railroads, jobs in the processing plants, jobs in the feed mills, jobs for salesmen and accountants, for chemists and engineers and carpenters and builders, that would not have existed during those years had it not been for the rising tide of soybeans.

Because those jobs were created by the production on the farms of a new and needed crop, there was money to buy food and clothing, automobiles and household goods, that otherwise would have found no markets. Thus in turn other new jobs were created to build the automobiles and to dig the iron for them, and there was business for grocers and merchants whose doors might otherwise have had to close.

Crowding into millions of acres that otherwise would have been adding to the surpluses of corn and oats not so much needed in those years, soybeans undoubtedly helped to prevent the prices of those and perhaps other crops from falling to even lower levels. The soybean money helped to meet mortgage payments, to send youngsters to school, and to improve the standard of living on tens of thousands of farms.

All this came about by producing a crop of value which met some of the country's needs and for which people were willing to pay. The soybean gave America more protein for human and for animal food. More protein was needed. The soybean gave America an added supply of vegetable oil. That, also, was needed in the national economy. It did more. By stimulating the imagination of scientists and of men of industry, the soybean has become a great industrial raw material out of which old things are being made better and new things are being added to the national standard of living.

No, it is not possible to calculate nor even to estimate what the soybean has done for the people of the United States. We shall have to be content with the certainty that it has added enormously both to the wealth and the welfare of millions of people.

Now let's explore another aspect of the soybean's career. We agree that it has brought a tremendous amount of wealth that we did not have before. From whom was all this wealth taken away?

There are those, you know, who believe that this is a mature nation, a nation that will grow no more. All the pioneering is done. Their doctrine is that since nothing more can be added, the time is come in our old national age when we can only share that which already is in existence. If they are right, this wealth must have been taken away from some one else.

The soybean was brought here from China. Did we therefore take this wealth away from the Chinese? They are probably growing more soybeans than ever before. If they export fewer to us, the advantage is theirs. The Chinese, with a standard of living hardly a tenth as high as ours, have never had enough soybeans nor enough of anything else for their own use. If they grow and use more of the crop themselves they are better off for doing so.

Did the soybean take its wealth, then, away from the producer of corn? I hardly need ask any corn grower here if he believes he is worse off because of this new crop. Did it deprive the oats grower? Obviously not, since he grew fewer acres of oats and more of soybeans.

There is but one answer to this train of interrogation. The great wealth of the soybean is new wealth. The new soybean dollars were created by the toil of farmers out of soil and air and rain and sun; they were made by the work of men in the mills and on the roads and by the salesmen who took the products to those in need of their new values. The soybean dollars are new dollars. They have not been taken away from anybody. They are dollars that would not have existed except for this new crop and the work that has been invested in its production.

The truth, then, must be that they are wrong who say this nation is mature, that no pioneering is to be done, that more new wealth is not to be created in America! The soybean has proved them wrong!

The soybean proves beyond the shadow of doubt that wholly new wealth can be created in tremendous volume.

CHAPTER VIII

New Crops for Wheat and Cotton Lands

I

NEW wealth which might be created in the United States by the introduction of new crops can be measured only in the imagination. This chapter is devoted to exercises of the imagination on this topic. Assumptions are advanced which the as yet very limited knowledge of man is incompetent to guarantee. The reader is invited to loosen a few of his moorings from demonstrated facts and proven practicalities. He need not, however, embark into a space devoid of principles and starting points.

The existence of astronomical bodies has been predicted as a result of established observations, and later, as with the planet Pluto, the body was discovered. Scientific hypotheses, a fine phrase for good guesses, are regularly proven by later determination of facts. An extensive foundation is available, on which to guess that substantial additions to the crop repertoire of American agriculture are possible and even likely.

A crop, of course, is the commercial harvest of a number of plants which have been sown or set out for the purpose of being harvested. While one may have a crop of zinnia seeds from the flower bed, normally a commercial crop is regarded as something grown in quantities equivalent to carload lots. A new crop, for the purposes of this discussion, is one not now commercially produced in the United States.

The number of commercial crops now cultivated by American farmers is about two hundred. An exact count would have to be preceded by further definitions. A number of farmers produce a crop of corn which, because of particular and expensive methods used, can be sold for seed purposes at eight dollars a bushel, while they also produce other corn the feed or commercial value of which is the same, but which may sell for a dollar a bushel. Naturally on the farm these are considered separate crops, but they are both corn. Popcorn and sweetcorn are separate crops. If one were to include in the count a few drug plants or rare seeds which, though grown commercially, are produced in very limited quantities, he might increase the list to more than two hundred. As a matter of proportion, the number of crops that create any substantial amount of commerce does not greatly exceed a single hundred species. Nine crops occupy 90 per cent of the annually harvested crop land—wheat, corn, oats, cotton, hay, barley, rye, flax and buckwheat. (The hay crop, of course, includes many species of grasses and legumes.)

In various parts of the earth crops are harvested from species which do not grow in the United States because of climate; most of these are tropical, since this country has about every other variation and combination of variations of climate, rainfall, soil, altitude and other elements affecting the growth of plants. A few crops are harvested on other continents but are not grown here because they are not esteemed here. A liberal estimate might allow that one thousand plant species are grown as crops somewhere on the earth.

Willard N. Clute, editor of *The American Botanist*, undertakes in *The Useful Plants of the World* to catalog the species which his title describes. Mr. Clute's highly interesting lists may be summarized as follows:

Food plants, a total of 517 species, of which 123 are commonly found wild and 394 cultivated.

Drug plants, a total of 298 species, of which 87 are wild and 211 cultivated.

Condiments and perfumes, 166 species.
Beverages, 56 species.
Masticatories, 11 species.
Fiber plants, 86 species.
Dyes, 62 species.
Soaps, 16 species.
Tannins, 21 species.
Gums, resins and rubber, 74 species.
Fatty oils and waxes, 64 species.

Mr. Clute's total number of useful species thus is 1371, of which 211 are indicated as usually found wild, leaving 1160 cultivated species. I have not made a cross analysis of the listings to determine how many times the same species may be repeated in different lists, but have noted such instances as pumpkin, first in the food plant list and then also as a drug plant, since the seeds have medical uses. This would further reduce the total from 1160 cultivated species. On the other hand, Mr. Clute does not undertake to count the species of trees used for wood, some of which are cultivated. If one insists on defining a commercial crop as carlot quantity production in a given community, the estimate of one thousand species of plants grown on the face of the earth as crops is likely quite high. Only a few of the large number of species used as drugs, condiments and perfumes would qualify.

Are these all the plants which have economic value to man? After all, he has been on earth quite a while and might be expected to have decided what was good and what was not.

In contrast to the two hundred commercial crops grown by American farmers, and to the world estimate of one thousand crops, stands a strikingly larger figure. According to estimates by competent botanists, the total number of identified and classified species growing on the face of the earth is around 335,000. The number of species indigenous to the United States and Canada is 15,000.

II

Nearly all the cultivated crops have been known to man since long before the time of written records. No history can describe the process by which wheat or rice ceased to be wildlings and became the cultivated servants of man. Maybe some brilliant though hairy and hungry ancestor of yours or mine noticed some rodent's store which, luckier than its gatherer, had survived the winter and was sprouting in the spring sun. Perhaps he evolved the tremendous idea of saving and protecting seed from October to planting time in May. However the idea managed to penetrate the brain of man, it was indeed a stupendous conception. Here was one of the few ideas without which no civilization could have been created. Storage of seed was the basic idea of agriculture.

At any rate, the common crops long preceded the chroniclers. Rare are the additions to the list. Now and then a wildling, admired for its beauty or treasured for medicinal virtue, has been lifted from the glade to be propagated in the garden, but these are few.

The thought-habits of the human race are deep-seated and do not change readily. Until a little more than a hundred years ago most men lived in most respects no differently than their ancestors had lived through many previous centuries. Since generations far prehistoric a few hundred plants have been esteemed as valuable and all the others as of no interest unless, because they insisted upon competing with the crop plants, they were regarded as weeds and especially objectionable.

Then, almost suddenly, human beings began to invent tools, to find improved methods of doing work, to build engines, to harness electricity, and to develop new knowledge of the elements of the earth. More progress was made in a few decades than in all previous history. The great spurt followed after 1789 when American freedom was organized.

Some of this outburst of new thinking was directed to the affairs of agriculture, but in no happily proportionate amount. Perhaps the visible rewards of application to industry and commerce were so much more tempting to ambitious individuals that few looked very hard for comparable new ideas in agriculture. Most of those few were men who made something to sell to farmers. Their thinking has advanced agriculture by long strides, but the idea of new crops was not their subject. For the most part, the old thought patterns with regard to crops continued undisturbed.

Only recently has it been pointed out that an entirely new set of valuations applies to plants. Once the only questions had to do with whether the plant could be eaten, or worn, or used to build houses. The rise of organic chemistry creates a wholly new set of criteria:

Any plant on earth may now become a crop if it yields a compound which the organic chemist can turn with profit to the use of man.

Further, the appearance of the plant geneticist enlarges the prospect of making a new crop plant economical. The application of his arts as a plant breeder may improve the desirable characteristics of the plant and adapt it to the conditions of cultivation.

Emergence of the agricultural engineer brings another set of effective forces to bear on plant materials. The engineer can create equipment and find applications of power which surmount expense and difficulty of production that once may have been too great to warrant the effort of cultivation or handling.

The preparedness of this potent trio, the chemist, the geneticist and the engineer, now demands that every genus and species of the plant life of the world be re-examined and its potential values re-estimated. The crop possibilities of a plant can no longer be dismissed merely because it is not readily convertible by simple mechanical means into food, fiber or shelter. Indeed, more than a few plants may now grow totally uncultivated and wholly ignored, which are capable of filling desires of man as yet wholly unimagined and unconceived. Few ever desired radios until radios were made!

New crops are most likely to become established because proof is apparent that they will fill an existing need, either better than some other material can fill it, or more conveniently than the need can be filled by importation. Those, however, are not the only possible conditions upon which to base a new crop study. For example, a universal and unfilled need is recognized for something that will cure the common cold. If there is a chance that anywhere in the world there grows a plant containing an element gifted with the property of curing colds, that weed would be more worth searching for than a new oilfield. It would make a new crop with an almost universal market.

No one knows, of course, that such a species exists. Neither does any one know that a cold-cure plant does not exist! Ephedrin, a drug useful in the prevention of colds, is taken from an Asiatic plant called *ma-huang* by the Chinese. Quinine comes from the bark of *cinchona*. Drugs from nearly 300 plants testify that the suggestion is not wholly fantastic.

III

Before exploring the practicability of hopes for new crops, an examination of the need for them may be appropriate. Why should new crops be sought? What reasons encourage expectation that new crops may return more in economic and social value than the crops farmers now produce?

Five major considerations support the contention that every effort ought to be made toward the addition of profitable new plants to the crop repertoire of American agriculture:

1. Agriculture needs enterprises that pay better than wheat and cotton under normal conditions.
2. The national defense demands reliable domestic sources of a variety of materials for which the country has been dependent upon distant overseas supplies.
3. Labor needs the assurance of employment and business needs the stability which a profitable and stable agriculture can guarantee.
4. The federal treasury (the people's pockets) needs relief from the farm relief which excessive production of certain crops built into a political habit.
5. Plant substances, inexhaustible in potential quantity and ever-renewable in supply, afford the largest single new frontier for economic expansion and for enrichment of human living standards.

IV

For much of the last quarter of a century wheat has been a problem crop. Normally more wheat has been produced every year than could be sold at prices reliably profitable to the growers. United States farmers produce roughly one-fourth more wheat than the country cares to consume. The excess or surplus each year has to be exported, carried over, or given away.

A natural question arises as to why, in the face of chronic overproduction and uncertain returns, farmers insist on continuing to produce wheat. Forty years ago, when buggy buyers turned to automobiles, the buggy manufacturers also turned to automobiles or went out of business. No chronic surpluses of buggies were piled up and, if there had been, one may doubt whether "buggy relief" from the federal treasury would have been forthcoming.

The question has a logical explanation in the fundamental nature of the business of producing wheat.

In the United States a very large portion of the wheat crop grows in the Great Plains area west of the one hundredth meridian, which runs down through the center of the Dakotas, etc. The wheat belt ranges north from West Texas through Oklahoma, Kansas, Nebraska and the Dakotas, extending westward into parts of Montana and Idaho, Wyoming and Colorado. In Washington, Oregon and California are sections where wheat is the main crop. All this is land of limited rainfall, much of it with half or even less the precipitation that dampens the lands in the cornbelt and from there eastward. The vast level stretches are easy to till with large machinery. Given a year of moderate moisture and no serious devastation of insects or unseasonable weather, the soil produces wheat. The good years come often enough, with their abundant yields, to encourage the wheat farmer to stay in the business. When he owns the land, when his whole investment is in his acres and the tools that grow wheat, he cannot well persuade himself to go elsewhere while the hope of another good year is before him. If the prospects are poor no one wants to buy him out at what he regards his holdings to be worth. He knows wheat farming, and hesitates to undertake to make a living in another occupation with which he is less familiar.

Wheat is sown persistently in the humid states of the north for entirely different reasons. No other crop is quite so dependably good as a "nurse" for young seedings of the hay plants, especially timothy and the clovers. Wheat may not be necessary on the diversified farm, but hay is necessary, either for feed, or because the legumes are desired to renew the soil's supply of nitrogen. Wheat fits into the rotation. In these areas it is sown in the autumn when the work does not add to the rush of springtime. A granary of wheat is desirable as home-grown feed for poultry and livestock. When the price is good it is among the better cash crops.

So, despite the fact that except in the war intervals wheat is usually a surplus and problem crop, wheat continues to be grown, and grown in such quantities that the price is determined by world production and demand. Canada, Argentina, Australia, and Russia also produce huge quantities.

The Great Plains farmer keeps on raising wheat because his soil and climate, though excellent for the great bread grain, are unsuitable for most other crops. In a few areas there is a choice between wheat and flax, but flax has been uncertain of yield and little more stable in price, with disease problems more serious than those of wheat. The farmer of the humid northern states grows wheat every year because it performs a service for him better than other crops and, even if it doesn't pay much, he still has other sources of income.

Such are the domestic conditions which have led American agriculture to remain in the business of wheat production and to face in a world market the penalties of competition with producers on other continents. The wheat farmer grows wheat because he has little choice in the matter. He is not dumb, unless habitual hopefulness is dumb. He knows that wheat is a basic food, that the world needs lots of it, and that every now and then a year comes when he is well paid for his crop.

A new crop, or a number of new crops, that would pay returns a little more satisfactory than wheat, could help to stabilize wheat production. If the new crops were sufficiently attractive to farmers and enough in demand to supplant about one-fourth of the acreage now cultivated in wheat, American wheat production could go on a domestic basis. The wheat farmer could escape the fluctuations of world markets, world demand and world production. Domestic consumption does not vary greatly from year to year. Farmers could grow enough to supply the needs of American consumers at American prices, along with enough carry-over to assure an ample supply, or to export if the foreign prices were attractive.

The new crops to stabilize the wheat business would be most effective if they could be grown in the Great Plains areas. They are most needed there, where the present output is usually wheat or nothing. They would permit a degree of diversification that now is impossible.

New crops suitable for a quarter or more of the wheat lands could take wheat out of politics and leave this ancient and honorable cereal where it belongs, in the worthy business of supplying a basic food to every American table. So little does the price of wheat affect the price of bread that consumers would not notice the difference in the cost of living if the price were consistently on a level profitable to the producers. It is reasonably certain that the earning power of consumers would be benefited in larger proportion from the improved stability that regularly-prosperous wheat growers could contribute to the national economy.

Is there among the 335,000 known species of plants one that will make a paying crop on the Great Plains and that will yield a commodity Americans will buy more willingly than they will buy four loaves of bread when they want only three? No one knows. Men have gone out into the world and brought back new and better strains of wheat, but few have gone to look for plants that will pay better than wheat on the Great Plains. Those who have gone out as plant explorers have looked for additional food crops, often for other cereals. None has looked with the eyes of the organic chemist for a plant capable of flourishing on the Great Plains and capable of feeding factories instead of stomachs.

Ten billions have been paid to farmers in recent years out of the federal treasury, while accomplishing no permanent advance towards taking wheat or cotton out of the problem-crop class. Such a stupendous amount of money would have paid for exploring almost every square mile of nearly every far corner and recess of the earth likely to produce a plant suitable for the U.S. wheat lands, and for all the chemical and engineering research necessary to determine the economic values of every promising prospect.

One new crop that would do for the Great Plains what the soybean has done for the cornbelt would solve the wheat problem. No one knows that such a crop cannot be found, and until an exhaustive effort has been made no one can be sure that such a discovery cannot be made.

V

The other great problem crop is cotton. For more than a century American cotton has been a leading export crop. Until very recently no one contemplated the possibility that foreign demand for American cotton might fade away. No other part of the world appeared to be able to produce cotton so abundantly and so cheaply as Dixieland. Forty per cent or more of the annual output was normally exported and the domestic market took the rest.

The present status of cotton is critical, far more serious than the wheat situation. Cotton feeds millions of people who earn their living as farmers, as field hands, as dealers and processors. Wheat maintains no such large population of dependents. Formidable competitive areas elsewhere in the world are offering their cotton in the marketplaces at prices which none of our growers desire to accept and few can afford to accept. Political relief policies have in effect priced American cotton out of its former world markets.

Meanwhile domestic competitors to cotton have made themselves formidable. Cotton, wool and silk once dominated the field of fabrics. Now paper, rayon, new protein fibers and nylon have risen to dispute their supremacy. Cotton is cellulose, and so is wood, and so are rayon and paper. Progressively more efficient methods of manufacture have cheapened and improved the competitive fibers. The policies that threaten to price cotton out of its once-safely-held foreign markets threaten the same effect upon cotton's domestic markets. Once other materials are accepted by the public to be as satisfactory and as cheap, careless King Cotton will need to look well to his crown.

Cotton has truly been a heedless King, a monarch far too long thoughtless of his responsibilities to his subjects and reckless of the protection of his empire. The poverty of the masses of his people has long been notorious. He has never paid his labor well. He has enriched the few, damned the many to barren lives in comfortless shacks. He has sought to monopolize the land in states rich with sun and rain and originally rich of soil. He made both soil and people poor when the soil, but for him, might have remained rich and might have made the people rich.

At a luncheon table in a southern city in 1939, the gentleman at my left was the head of a large cotton mill.

"We have not used a pound of American cotton in twenty years," he said during the conversation.

"Now we are having trouble. Our cotton comes from India. It is a short, coarse, kinky fiber obtainable only there, and the only kind of fiber suitable for our products. But now no ships can be found to carry it here from India. We are trying to engage Japanese bottoms."

"Have you ever imported the seed from India, and tried to grow the cotton here?"

"There would be no point in that. They produce it cheaper in India."

"You have never looked around to see whether any such cotton might be grown here? Or whether any sort of treatment would make American cotton suitable?"

"Oh, a fellow sent us some once from Arkansas that looked about the same, but we didn't bother about it. Cheaper to use Indian cotton."

Thus, with rare exceptions, has it been with the princes and the favored nobles at the court of King Cotton. Knowing how to buy, spin, weave, hire cheaply, and sell, they have seldom been aware of the need to know more. Research in other fibers? Why think of it; has not cotton always been King? Research to improve cotton, or cotton products, or manufacturing processes? Why spend all that money?

Hence fibers with active laboratories behind them crept up behind the throne of King Cotton. Eventually frightened by their threat to the security of his realm, he rushed to the politicians rather than to the scientists. They doped him with loans and price supports, cheerfully unaware that these were toxins to put him to sleep at a time when his situation demanded tocsins to wake him up.

The upshot has been that cotton remains the number one agricultural problem while the rain and sun of the cotton South may very well make Dixieland the number one opportunity area in American agriculture and industry.

Like every economic problem, at base the cotton situation is a maze of human problems. Several million farmers, white and black, owners, tenants, share-croppers and hired hands, know cotton and do not know other kinds of farming. Thousand of towns, thousands of individual and corporate dealers, ginners, compressors, bankers and all the links in the web of an economy know something about cotton and little about other ways of prospering.

To further upset the old faiths in the white fiber come now the engines that plow, chop, cultivate, burn the weeds and even pick the crop. The mule and his driver alike are confronted with something cheaper. Cheaper, that is, for the big fields and level lands in the Mississippi Delta and Texas. For the little patches and rougher terrain of the old Southeast, where the big equipment will not work, mechanized production to the westward may signal compulsory shifts to other crops or abandonment of land.

VI

One can barely guess what new crops might prosper in the wheat plains. New crops for the cotton lands are already growing under the southern sun. True, they need research to further cheapen the costs of their production and processing, more study into their uses and markets and, in some instances, protection from foreign competition. Unlike cotton, which cannot be protected in world trade, the new crops aim wholly for the home markets and can be sheltered if necessary.

Here is a simple hypothesis in a single complex sentence which may need to be read slowly: *If the cotton states produced vegetable oils in quantities equivalent to the amounts normally imported, more acres would be required than were customarily occupied by cotton for export.* In other words, cotton *could* be removed from the relentless price pressures of world competition and, once largely on a domestic market basis, could become a regularly prosperous crop.

So far as pure agriculture is concerned, the oils can be grown. Even if no more cotton were planted than the domestic market could use, cottonseed oil would continue to rank as an important by-product.

Peanuts grow well in most of the cotton states. Between

1939 and 1943 their production doubled from 1,211,710,000 pounds to 2,561,610,000 pounds. Peanut oil is valuable.

Strains of soybeans are being adapted for southern conditions. Tungnuts, the most useful of all drying oil sources, can be extended somewhat beyond the present groves. Sunflowers will grow and might have a chance.

Okra, that slippery garden vegetable to which the southern taste is unaccountably devoted—the one my friend says "goes down before you can swallow it"—will yield from a half ton to a ton of seed per acre with 16 to 22 per cent content of oil. Because the seed remains on the stalk after frost, the plant can dry in the field until harvested with a combine during the winter. The Louisiana Experiment Station, which has studied okra, says the oil's qualities are approximately those of the oil from cottonseed, and that means good. Other states are making cooperative tests.

The castor bean, whose oil when dehydrated is as valuable as tung oil for half of the latter's purposes and nearly as valuable for many others, still struggles in the South to win a commercial toe-hold against imported beans.

Perilla, another high-grade oil seed, has been found to grow abundantly but awaits mastery of the harvesting difficulties.

These do not exhaust the list of oil plants known to flourish under the same sun and rain and in the same warm air that make cotton grow.

True, their oils are not exactly the same as the coconut oil, palm oil, palm kernel oil, babassu, oiticica and other oils gathered by exploited natives of the tropics for a dime or a quarter a day. But the organic chemist is a master of oils. He can not do quite everything, but he has a great knack of using whatever oil happens to be cheapest for his purpose. The Southern Regional Research Laboratory has lately presented a new demonstration of this in a new process for using cottonseed oil for terne plating steel, an operation hitherto dependent on palm oil.

Oils, moreover, are by no means the only kind of alternate crop for the surplus cotton acres. The molecules of starch also build up fast in the southern air. And, as was previously pointed out, starch is a tremendously important industry.

From the tropics, principally from the distant, populous coolie regions of the East Indies, the United States has been accustomed to buying upwards of 350,000,000 pounds of tapioca starch a year. The cassava and arrowroot of Java do not flourish in Dixie, but sweet potatoes do. And sweet potato starch will go in industry, even on a postage stamp, as far as tapioca starch.

The tired and hot old cotton fields can grow oils and starch. They do grow oils and starch. Research and sensible national attitude toward them can help them to grow far more. They can produce better pastures and raise more meat, eggs and milk for the country's diet.

Search of the earth's surface, examination of the world's flora, undoubtedly would yield other plants that will make money where cotton loses money.

CHAPTER IX

A Farmer Works at Chemurgy

I

A BRILLIANT new approach to one man's cotton problem was conceived in 1936.

The man was D. Howard Doane, a canny, scholarly-looking, philosophical man of action. Gifted with one of agriculture's notably creative minds, Doane long before had displayed conspicuous capacities to think ahead and then to act. As a country youth toiling his way through the Missouri College of Agriculture he conceived and organized the Farm House Fraternity which politely turned its blind side toward the Greek letter fraternities. While still in college he read an article by W. J. Spillman which remarked that the management of land ought to be regarded as a profession on par with the learned professions.

"That," said Doane, "tells me what I want to do in life."

After experience as a teacher, county agricultural agent leader and Department of Agriculture worker, Doane undertook the management of some Missouri farms for a non-resident owner. The farms began to pay. Other owners engaged him. He set up the Doane Agricultural Service with a designation that set no particular limits to the type of service that might be undertaken when customers appeared. To possessors of farms who were dependent on tenant operation an attractive proposal was offered. Doane undertook to select tenants, to recommend and oversee repairs and improvements, to plan and direct the farm's production program, to attend to taxes and insurance, and at stated intervals to make complete reports to the owners. The idea worked so well that farms grew in number until from 1930 onward the Doane Agricultural Service was supervising, either for direct operation, improvement or liquidation, between three and four hundred thousand acres. Branch offices up and down the Mississippi Valley looked after land north into Minnesota and south towards the Gulf of Mexico. Doane had been right about what he wanted to do.

Farm management proved to be a professional opportunity so sound that others took it up. Among them were small-town lawyers and bankers who were rent collectors rather than managers. Doane invited a group of the competent men together and proposed the organization of a society with carefully drawn professional standards. This today is the American Society of Farm Managers and Appraisers, with several hundred members. A candidate who can prove his experience and can pass the examinations may join.

The father of professional farm management had found himself a cotton farmer when the owners of large Mississippi plantations became his clients. Cotton production, as normally conducted, was interesting. Its future, Doane thought, might be troublesome. He didn't like competing with half-starved fellahin and the coolies of Asia. The prospect for ordinary cotton looked gloomy.

Even before the name of chemurgy was born, Doane had risen with practical enthusiasm for the idea. A speaker at the First Dearborn Conference and a participant in most important conferences thereafter, he has been an active and highly regarded member of the Board of Governors since the organization of the Farm Chemurgic Council. He knew thoroughly the philosophy of new uses and new crops, and believed in the doctrine. Characteristically, he looked for ways to make the idea work.

II

One day Doane appeared in the executive offices of a large rubber company. The following quotations have been confirmed on both sides as substantially accurate.

"I believe," said Doane, "that you use in tire manufacture considerable quantities of cotton which is imported from Egypt."

"That is correct, sir."

"I understand you use the Egyptian cotton because you find in it certain peculiar qualities not generally possessed by the American fiber."

"Yes, that is why we have to have it."

"If I should offer to sell you American cotton with the same characteristics, equal or better in quality, would you buy it from me?"

"Why, I presume we would. But you produce no such cotton in Mississippi!"

"No, not at present. Would you mind giving me, in full detail, the exact specifications of the kind of cotton you want?"

The whole idea must have sounded more than a little fantastic to the rubber men. But there was a convincing air about this forthright farmer who laughed pleasantly and looked at them through his glasses with such innocent seriousness. Painstakingly they explained that the value of the Egyptian cotton depended upon such things as its greater length and uniformity of length, its fineness of fiber and the uniformity in that respect, its spirality, tensile strength, and other points. In all there were eight indispensable specifications which had to be met.

Doane thanked them politely, looked at his watch, and left for Mississippi.

III

Among the other things in Doane's mind at that particular time was a fact. He respects facts. He had for some time doubted whether the cotton business had been sufficiently concerned with facts. To his mind there was something ridiculous, for instance, in the long-prevailing methods used to grade cotton. Yanking a random sample out of a 500-pound bale, the grader pulled the fiber through his fingers, looked at it a moment, and declared that it was cotton of such-and-such length staple and grade. Doane thought it was hardly reasonable to accept this as an accurate assessment of value, especially considering that there were forty-five billion fibers in a whole cotton bale.

The strength of cotton fibers for a century had been assumed to depend on the length of the fiber. The long-fibered Sea Island and Egyptian cotton, too low in yield for profitable production on most of the South's cotton lands, was bought for its strength, a factor of particular importance in tires.

The significant fact which Doane was rolling around in his mind in those days had been discovered by Dr. R. W. Webb, a scientist in the Department of Agriculture. To Webb a question of extraordinary simplicity had occurred. What would happen if he clipped some of the long-fibered Egyptian cotton to the same length as ordinary American cotton staple? He did just that, and wove the shortened fibers into yarn. Then he compared the yarn with yarn from American cotton. It had turned out to be stronger by half.

This had exploded the theory that long fibers meant strength. What, then, did produce strong cotton? The obvious deduction was that fibers of less diameter, finer and silkier, wrapped themselves into a stronger and tougher yarn. Doane believed it possible that a finer American-grown fiber, even though shorter than Egyptian, might meet the tiremaker's needs.

Nor was that the only idea in his mind. The maker of shoes with cotton tops needed cotton with the uniform quality of resisting the rough scuffing which usually wore out the tops while the rubber soles were still good. The manufacturers of fire hose, of canvas, of towels, needed cotton fibers of particular characteristics. Why not find out the specifications for the use of each mill, and grow cotton to suit definite needs?

IV

At the Mississippi State Agricultural College Doane picked out a newly-graduated student who was interested in plants but had no Ph.D., and was "young enough not to know that what we were going to do couldn't be done." John W. Oakley was the young fellow's name, a lad from a family of twelve. He had worked his way through school. When he protested that he came from the east Mississippi hills and knew nothing at all about cotton, Doane merely said, "That's fine. Come right on with me."

Under Doane Agricultural Service management was the Robertshaw Plantation, 7000 acres at Heathman, Miss. (The property is now called Bobshaw Chemurgic Plantation). By July, 1936, young Oakley was living there, walking day after day up and down the long hot rows of Robertshaw's 3000 acres of cotton. He was not pursuing the scientific techniques of the geneticist who painstakingly chooses strains and pollenizes, crosses and backcrosses. His assignment was to see what vagaries nature had played on these 3000 acres. Whenever he found a cotton plant whose leaves, stalk, color or shape revealed evidences of a characteristic different from those of its more average neighbors, he drove a stake in the row to mark it for further notice.

By cotton-picking time he had driven 1400 stakes. That was the summer's work.

The bolls from each of the 1400 distinctive plants were picked and chucked into a separate paper bag. The bags were piled in an old open shed that he had cleared to serve as a laboratory.

One by one through the winter Oakley opened the bags. With a tiny miniature gin he pulled off the fibers and set aside the seed so that he knew to which handful of fibers it belonged. The rest of his laboratory equipment was a comb and a ruler. With these and with keen eyes and strong, sensitive fingers he compared fibers week after week, tossed out bags, carefully kept back a few for further observation. Most of the samples proved to be just ordinary Mississippi cotton, worth no more in Liverpool or Manchester or Akron than any other common cotton. A couple of hundred were a little different, though, and nine of the samples looked rather promising.

These nine samples were planted in the spring of 1937, along with a few dozen of the others, where they could grow under daily observation.

By the next winter a microscope and some other testing equipment were put to work. Another crop was grown in 1938. The following winter the expert laboratory technicians of the big rubber company, amazed and incredulous, were asked to check the observations of the young plant student who had tackled the job that could not be done.

Then came cotton picking in 1940. There had to be special care in the fields and at the gin to see that the new cotton was kept unmixed.

By this time young Oakley had achieved a keen awareness of the revolutionary importance of the job he had undertaken. He was seeing, more clearly than at any time yet, what his work might mean if this 1940 crop of cotton was accepted by the mills for what Doane and he hoped it might be. One may very well imagine that the fall of 1940 was going to be a highly special occasion in the life of one John W. Oakley.

And so it proved to be. In the profound wisdom of Selective Service his value to his country would be greater if he learned how to carry a rifle than if he were permitted to proceed with his scientific enterprise. He was drafted and, perhaps to justify the board's judgment, proceeded to work his way up to a captaincy.

At the rubber company's factories there was a very special occasion, too. For here came 3000 bales, regular 500-pound bales, of the first cotton the world had ever seen that was grown to precise industrial specifications.

The laboratory men said it looked all right. They could be pretty sure of that. A breaking strength of 80,000 pounds per square inch was as much as the industrial demand required. Here were some samples whose strength exceeded 100,000 pounds per square inch. Some grades of steel could not meet that test.

Into the mills it went, and into tires. The tires were put on the testing machines and on to the wheels of automobiles, where they were subjected to gruelling wear. The American cotton grown to specifications was not merely as good as Egyptian cotton; it was better!

The final check for the shipment was sent to Doane. The rubber people paid a healthy premium.

Chemurgy, mused Doane, as he sent the check to the plantation account, is a very practical idea.

The next year he shipped 15,000 bales that met the specifications. Seed in quantity began to be available. Arrangements were made with other planters to grow the crop at a premium over the market price of two cents a pound. All the seed is returned to Doane, for which he pays also a premium. Only by having full control of the seed can he assure the quality of the crop.

Oakley's absence and the demand upon cotton mills for maximum production have prevented orderly expansion of Doane's cotton program. The course of time undoubtedly will reveal highly important points that are not yet fully appreciated.

For instance, Doane's Bobshaw cotton varieties do not compete with any other American cotton. They are, in a sense, out of the world market, in that they compete primarily with Egyptian fiber. To whatever extent they expand to supply the one particular need, they will not be adding to the surplus of the common Southern cottons.

Mills able to obtain specification cotton, definitely uniform in quality, will enjoy a measurable economy in operations and reduction in waste.

Consumers will be benefited by receiving better products than formerly could be made.

Planters who grow the cotton will receive the premium price; moreover, experience so far has indicated that Doane's cottons yield more pounds per acre.

Chemurgy inclines to the belief that when the facts are obtained and are favorable for going ahead, nobody loses.

V

D. Howard Doane is the sponsor of what he has called "Vertical Farm Diversification." The idea is so constructive, in many of its phases so pertinent to chemurgy and the implications so far-reaching that it deserves extensive exploration. Rather than to present the topic in an inadequate, secondhand manner, I have asked permission to present here one of Doane's own statements. Considered along with his achievement for producing cotton to industrial specifications, his program for vertical diversification will be seen to fully justify his early confidence in the practicality of chemurgy.

VI

Mr. Doane says:

In diversifying vertically the farmer follows his most profitable crop or crops one or more steps beyond raw production. Instead of turning them over to others at the gin, elevator or packing plant, he himself performs the next steps. Vertical farm diversification contrasts with our old thoughts about diversification, which I call horizontal diversification, in that the latter means growing more and more of the less-and-less profitable crops. This type of diversification has the further disadvantage of keeping farmers in the exclusive field of raw production.

As long as any of us can remember we have been told that the trouble with the wheat belt was that the farmers grew too much wheat; the difficulties of the cotton belt were caused by too much cotton, and so on through each of our major producing belts. Why have farmers disregarded these repeated warnings? For two reasons: First, they are not true. Second, no one has yet found a more profitable crop for the South than cotton, and for the West than wheat, and for Florida than citrus. True, the cotton belt has not always been prosperous but what little it has had has come not from cowpeas and corn but from cotton.

The cotton farmer's trouble arises not from exclusive cotton production but from exclusive raw production.

Now he is wholly dependent upon raw production while others pick up his product and gin it, store it, press it, haul it, factor it, insure it, squeeze it, (and him) and do all else on fixed margins while he as an exclusive raw producer takes what's left.

In vertical farm diversification all that he does is to take just a little larger share, not all, of the consumer's dollar. He again performs for himself some of those jobs his great grandfather did, and keeps for himself the fixed margin of profit that all processing and handling always demands. As a competitor with industry he is competing with someone who must have a profit to stay in business. As a competitor with a fellow farmer, that competition gets hotter and hotter as prices go down and continues even after profits go out. His neighbor will contribute the fertility of his soil, the depletion of his buildings, and the labor of his wife and children, and continue to sell at a loss. When the *profit* goes out for the processor then he quits. As a farmer I have found it much more satisfying to compete with the fellow who must have a profit to remain in business. My farmer competitors are not that easy on me. They bring in as much cotton at 5 cents, or eggs at 10 cents, as they do when prices are much higher.

VII

Without further explanation, let me give a good illustration of vertical farm diversification. I have just returned from Florida, where I made a rather careful study of the citrus industry.

Most of the citrus groves are small. This makes maximum-production economics impossible. In the past, handlers of the product have not been the producers. Thus, the little producer, so typical of all agriculture, took the price offered by the handler and hoped that there would be something left after paying production costs.

The owners of 40-acre orchards apply for co-op membership. Some are taken in with the understanding that the co-op will be the managers of their orchards as well as the packers of their fruit. The co-ops say they can market no better fruit than that which their members bring them. The grove owner who does not believe in a complete fertilizer or spray program cannot produce top grades; so, to get a uniform product and reduce production costs to the minimum, the groves must be handled in accordance with the last-known word of efficiency.

With 2000-3000 acres they can afford the newest and most modern spraying outfits. They buy fertilizer elements and run their own mixing plants. Sprays are made up at the co-op plant and the costs of these two items have been cut in half as compared to what the little fellow previously paid. With the best of machines a better job of spraying is done at *less* cost. When the soil specialist prescribes the fertilizer, just the right kind and volume is used so that in the end *more*, much more, crop is produced; quality is improved; and costs are lowered. Picking time comes and well-organized crews with full equipment and plenty of trucks get the crop into the sheds in the shortest time and in the best condition.

At the plant the fruit is sorted; the best is wrapped and carefully packed in boxes for sale as fresh fruit to the retail trade. Other grades go to canned juice. Part of this goes into a concentrate—one box of 90 pounds of oranges now becomes one gallon of product. The orange peel, rag and seed are now pressed, dried, and ground into an excellent feed, or perhaps taken to the extract room and made into pectin and glucosides. The peeling liquor is dehydrated and made into molasses, alcohol, or yeast.

Those who know something of the chemical properties of citrus feel that the by-products, which will ultimately come from the waste and other by-products, are of great potential value. Revenue from waste has already added to income and provided Florida with a new source of livestock feed.

Now let's analyze this example of vertical farm diversification from the business standpoint, via the shortest route—the fresh oranges. Here is the milk in the coconut; perhaps I should say the real juice in the orange. When oranges are $7.00 a box, about 40 cents a dozen retail, the grower has a chance to participate in 35 per cent of the gross while the other groups get almost double this, 65 per cent, *and every one of those industrial interests operates on a fixed margin, including a profit.* I hear you ask what will happen when oranges sell for $3.00 a box—what about the little fellow then? Well, that is easy to answer, because in the past *almost* all the difference has come off from him, that is, all that could come off. Figures show that in those days he got up to 15 cents a box for his crop, and down to minus zero, if there is such a thing, and had no *share* in any other parts of the business.

With vertical farm diversification, as these orange growers have worked it out, they will make money in the future even though the fruit is sold at cost of production on the tree, because they will share in the 65 per cent of fixed margins—the industrial margins, please note. Which group will be best able to stand the hard times that appear to be ahead? These growers who are now practicing vertical farm diversification or the exclusive producers? Of course, that is easy to answer. All in the business agree that with the war over and Florida producing the crops now most certainly in sight, and when markets react as they always have in the past, then the chances for the exclusive independent grower are so slim that he will in all probability go out of business.

To me this is almost the perfect example of modern vertical farm diversification. True, it goes farther than is ordinarily contemplated when we say, "one or two steps beyond raw production," but it does show the possibilities and has in it all the elements of the pattern from diversification below the production line, such as fertilizers and sprays, to diversification above the line in packing, processing, advertising, and selling. These groups have returned excellent dividends to their members *and* they now have the most modern plants in the state, all paid for out of member contributions. Not only have they diversified vertically but through research they have found new products from old wastes. One manager said he could run his plant on the profits from former wastes alone—the orange peel.

VIII

I will give you one more illustration before showing how broadly vertical farm diversification applies. Seventeen years ago we took over the management of a 7000-acre cotton plantation in Mississippi. It was producing about 250-300 pounds of lint per acre. During the last half dozen or more years it has averaged well over a bale to the acre. But in the face of this, and under what we hope is conservative and efficient management, we found that on average pre-war prices it was hard to make money on just pure raw cotton production. When our books were balanced at the production sale point and we counted cotton income at the price at the gin, then we, like hosts of others, found true profits were hard to make. A study of this situation revealed just what we have been discussing. We installed a modern gin—it has always made money. Its competition is other gins owned in town that must show a profit to exist. We noticed that the average price of cotton seed at the oil mill was greater in June to August than in September and October when most seed goes direct from gin to mill. We built a seed storage house and paid for it out of one crop. We bought pure seed and so sold planting seed to our neighbors—another profit.

Later, instead of buying our planting seed we decided to breed our own. We employed a plant breeder, developed the Bobshaw cotton, the first grown to industrial specifications; and our whole cotton research program paid dividends. Our organization and plantation is fairly large but still too small to perform some services best when working alone; hence, we joined a cooperative cotton-selling organization. It has paid. We have not yet established an oil mill for crushing seed, so again we joined a co-op oil mill and it has also been most profitable.

We have also carried vertical farm diversification below the line of production.

Our employees and tenants borrow money. We put in a bank—it pays a profit. Five hundred people eat lots of groceries and wear work clothes. We put in a store—it is profitable. We also purchase and sell fertilizers and insecticides. All these make money because as bankers, processors or retailers we fix and take definite margins. For our raw production we take what someone else says they wish to pay us.

Instead of taking further illustrations from individual crops, let us see what the future holds for vertical farm diversification. There are those who feel that the next major business shifts will be toward decentralization. There are many reasons for it: labor restrictions, laws, working conditions, taxes affecting big business, and many others. Out of this there will probably come new types of processing machines, made in small units for small rural industries. They should cost say from $5000 to $25,000 and be so constructed that they can be quickly and easily installed and simple to operate. Returning war workers and our boys who have been in the service have had excellent training in handling mechanical equipment. I suspect that many a farm boy would prefer to operate in a little community processing plant rather than go back to following the plow and milking the cow. Well, let's start our community cooperatives and give him a chance to help make vertical farm diversification a reality. Here are some fields for this consideration:

First we should remember that some steps in vertical farm diversification can be taken easily and at little initial cost.

The very simple process of hauling by means of an individually or co-operatively owned truck, which saves what would otherwise be a greater cost to a commercial truck or railroad, is a step in the direction of vertical farm diversification. Likewise the storage of a crop in a bin, warehouse or elevator, may also result in greater income to the producer.

Not in every case can the individual or a group of producers perform a given, non-productive task more economically than those who ordinarily do it. Before any contemplated service is taken over, careful figures should be prepared to determine the financial results which should follow. In each case trace the normal flow of the crop from the time it leaves the producer to its ultimate consumption. Study each step to determine if it can be handled more efficiently or more profitably by the producer. Only when the facts justify action should it be taken.

IX

Here is a list of fields or functions which can ordinarily be studied:

1. Hauling and transporting.
2. Storing and warehousing.
3. Brokering and factoring.
4. Insuring and bonding.
5. Cleaning and grading.
6. Ripening and conditioning.
7. Packaging, wrapping, canning, and preserving.
8. Advertising and promoting.
9. Wholesaling, retailing—delivering and servicing.
10. Processing, refining, finishing, and packing.

Inasmuch as farm and community processing is receiving a great deal of attention at this time, a few comments on some aspects of it might be made.

Extraction: A number of community plants have already been constructed for extracting oil from oil-bearing seed such as cotton, soybean, castor, sunflower, flax, peanut, tung, and perilla. At Ames, Iowa, they have worked out an oil solvent process for taking the oil from these seeds. These little Iowa plants have a capacity rating that makes it possible to locate one per township, so that each soybean grower could deliver his beans and take home meal for his livestock and enough oil for the paint he needs.

Digestion: Our consumption of paper increases at the rate of 250,000 tons per year. Present consumption of paper-making material, especially trees, is already at a point that threatens all of our available wood supplies. We will soon be consuming between 10 and 12 million tons a year. Formerly we imported large quantities of wood, wood pulp, and paper from Canada and the Scandinavian countries—sources which may not always be able to send us unlimited supplies. America must produce and save her own cellulose. The only large sources of unused cellulose are in the form of straw, and in the stalks of such crops as corn, cotton, and beans.

We can build small digestion plants that will separate the cellulose from the lignin and ship from them to the paper plants the pulp which they need and which is becoming increasingly scarce. This plan would leave in the country, at the source of production, the part that is most valuable from the standpoint of the soil, namely, the lignin—vegetable matter—and minerals, and ship to the paper factories pure cellulose which is derived from air, sunshine and water.

With the development of machines for harvesting and storing these waste products, and digestion plants for separating the cellulose for paper making, we can distribute over a wide area many useful and practical commercial operations in the producing areas of the United States.

Compression: One of the essential steps in gathering and transporting low-valued products from the farm is more efficient compression. Every farmer has had experience in baling hay and other types of products. We need machines which will do the job more efficiently and develop the compression to double that which is ordinarily found in the bale of hay. This will make it possible to handle products more economically and ship them farther. Probably types of compression can be developed for turning a straw pile into wall board. This process is now under investigation at the U.S. Northern Regional Laboratory, and should soon be available for use. Extremely high density machines for compressing waste products into briquettes will make them available for fuel.

Dehydration: Driers for hay, fruits, and wet grains have been made in the past and new types are already in sight. Hybrid seed corn operations have as one of their chief functions a dehydration plant. It is probable that a larger and larger proportion of milk produced outside the city milk sheds will be dried for home and commercial use.

Fabrication and Separation: Cotton farmers have lacked clothing when their cotton in the field was worth 5 cents a pound but they had to pay 75¢ to a $1.00 a pound for it in the form of overalls. Community plants have been developed for separating the fibers and spinning and weaving them into useful products on a community basis. The writer located a community spinning enterprise at Stratford-on-Avon in England. It was just before the war and its beginning caught us in the midst of a transaction for the purchase of the equipment. This type of machinery will have wide use in areas where such fibers as cotton, hemp, flax and possibly synthetic fibers from milk and soybeans are now being produced. There is no reason why agricultural communities cannot manufacture woven materials of a kind they most frequently purchase, such as denims, sacks, bags, and tarpaulins.

Refrigeration: Farmers are questioning the use of electric current for storing large quantities of perishable products if there is a chance to lose them as a result of interrupted current due to line failure. At the Texas Agricultural College a process has been worked out that will keep these refrigeration units cold for 8 to 10 hours after the current fails. The introduction of this emergency equipment may solve this problem. Quick freezing and cold storage will continue to grow as a farm and community enterprise.

Distillation: There is no community processing which would have as great an influence on agriculture as that which relates to distilling alcohol from waste farm products or crops grown for the purpose. Such plants would enable farmers to recover lost markets. The market for hay and oats, which disappeared with the horse and mule, will come back in the form of power for trucks, tractors, and stationary engines. This one community enterprise would absorb as much surplus corn and wheat as we have ever grown if only 10 per cent of the gasoline now being used is displaced by alcohol.

Concentration: We must find more efficient ways for gathering and concentrating low-grade farm products if they are to enter into commercial use. The old system of allowing one-half of our total production to be burned or wasted will not fit the new day agriculture. Ways are already being suggested for more efficient handling of hay, stalks, corn stalks, and other similar products.

Grinding and Crushing: The making of plastics, cleaning materials, and fillers for commercial feeds and fertilizers is dependent upon a system for more efficiently crushing and grinding many waste farm products. Experimentally it has been shown that finely-ground corn cobs make an excellent filler for plastics. Coarser portions of the cobs can be used, with an air blast, for cleaning carbon from motor cylinders and tile surfaces that would be injured by the use of sand. This is a phase of community processing not yet well understood but which holds unusual possibilities.

Construction: Community work shops, where purchased lumber and the products from tree crops can be turned into useful farm equipment, are certain to be a part of vertical farm diversification. Trees are a crop that should be harvested when mature and their products made by farmers into farmyard furniture.

Measuring Devices: With the coming of vertical farm diversification, plants which process farm products must be in a position to measure accurately products which they buy and sell. This will call for the manufacturing of a relatively wide range of measuring equipment which will reflect moisture content, density, porosity, size, tensile strength, concentration, and other measurable factors. Someone should be ready to supply these needed measuring instruments adapted to community processing.

X

In Conclusion: How strange that throughout the years, self-appointed advisers should condemn those areas that produce our greatest agricultural income, and continue to tell us to stop growing the very crop that makes us the most money. They have diagnosed our difficulty as specialization of production, and missed the real point entirely. The very thing they have told us to stop doing we should continue to do: grow more of our most profitable crops, and then diversify vertically by adding *processing* to *production.* It's not the one *crop* but the one *process* that has hurt us. There are good, perhaps necessary, features to some horizontal farm diversification, but certainly it has its limits in the number of different crops we can grow. Only man's vision is the limit to vertical farm diversification. There are practical limits to population density and the number of people agriculture under the old concept can support. When agriculture grows vertically—moves up—only the sky is the limit.

XI

The survival of the American freedom which has been enjoyed in this country for a century and a half, rests these days in precarious uncertainty. Outstanding among the conditions that threaten the continuance of individual liberty is the steadily increasing urbanization of the population. People who live crowded in cities when out of jobs and out of money, are soon out of everything necessary to living. They are, therefore, easily tempted to surrender freedom for the promises of security; and always there will be those, ambitious for power, who will promise security to the people in return for a portion of their freedom. That no statesmen ever yet have been able to deliver the promised security appears to be no barrier to the continued making of promises, for only a few of the people heed the lessons of history.

With the techniques of food production constantly becoming more efficient, a steadily smaller percentage of the population can make a profitable business of farming. Industry beckons to the others with the finger of opportunity. And as industry has been overwhelmingly urban, the trend of population from rural to city America has never been checked except by depressions.

Decentralization of large industry is only a partial answer. Seldom has industry genuinely decentralized; rather it has moved to the perimeters of existing industrial concentrations, frequently leaving a blighted center; or it has expanded smaller cities into big ones.

In vertical farm diversification forms of industrial opportunity economically practicable for rural areas present themselves. Chemurgy enters extensively into the many of the partial processes which Doane proposes. Chemurgy and vertical diversification together hold a profound promise for the American future. They point to a feasible means by which the destructive urban trend may be checked. Rural industry may be enabled to compete with urban industry in attractiveness for some of the people. When a man can have a steady job, a house and a garden and his own piece of the out-of-doors, he can create his own security. And, after Roosevelt, only a fortunate few will be able to accomplish that under urban conditions.

CHAPTER X

Chemurgy in the Everglades

I

A VIGOROUS rotund Rhode Islander came a few years ago into control of the United States Sugar Corporation, a large acreage of the Florida Everglades, and a troublesome sugar operation. Among the troubles was the need for 17,000 hands during cane-cutting season, and for only 5000 during the low ebb of the year's work.

Clarence Bitting is the man. He called in his aides and summarized the problem.

"Get some atlases and encyclopedias and whatever else you need. Find out where else on the globe there is land with soil like our Everglades ground. Find a place with the same kind of soil, same rainfall, same sunlight, same everything or the nearest you can come to it. Then find out what they raise in such a place."

On the coast of India there was soil and rain and sun like the Everglades. What did they raise there? Lemon grass.

"And what is lemon grass and what is lemon grass good for?"

Well, it was long grass. In primitive sorts of stills the people of India extracted from it an oil known to the trade as lemon grass oil.

"Why should anyone buy lemon grass oil?"

For furniture polish, among other things, and as an aromatic oil used in perfumes and soaps and toiletries.

The story of the endeavor to put the lemon grass operation on the black side of the sugar corporation's ledger illustrates the difficulties that may be encountered by a new crop. The illustration is all the more vivid in light of the fact that the task was undertaken by a large, well-financed, intelligently-operated company amply able to command all the resources of information, equipment, brains and experimentation that might appear requisite to success.

That lemon grass would grow abundantly in the Everglades soil and that it would yield a normal portion of the oil were easily determined. When the experiment was begun, good farm field labor could be obtained in the area for little more than a dollar a day plus housing and medical perquisites. Within ten years similar help was hard to find at four dollars or more a day. Thus one of the larger elements of cost fluctuated upward.

The peak price of the oil ranged during eighteen months, from April, 1942 to October and November, 1943, from $4.35 per pound downward to 64 cents per pound. Any effort to budget the financial operation a year in advance clearly was out of the question.

One year in the early forties the loss was $0.2069 per pound of oil. The second year thereafter the loss was $0.9176 for each pound of oil. American business had learned to figure decimals on by-products as well as on main products.

The oil from lemon grass was obtained by distilling the "hay" with steam. The spent grass lost nothing except the oil. So this spent grass or pulp was put through a dehydrator. Cane molasses, a by-product of the sugar operation, was combined with it. Protein concentrates, such as soybean or peanut meal, were added.

The 1943-44 operation had shown a loss of $31,459.92 on the lemon grass oil. The feed made a profit of $18,507.09. Thus the overall loss was reduced to $12,952.83. If the price of oil had remained at the levels of two years previous, according to Dr. B. E. Bourne, vice-president and director of research for the corporation, instead of a loss, the profit could have been $25,151.52. That would have been $22.08 per acre from 1138.8 acres harvested. The conclusion can only be that a price stabilized at a reasonable level could assure domestic production of a desirable product.

The sugar corporation has gone one step further. Instead of selling the feed, it bought range cattle and fattened them on the lemon grass-molasses-protein ration without grain. The feeding operation may well have pulled the net into the black column.

II

The lemon grass venture was but the minor prelude to a chemurgic undertaking of vastly greater dimensions. Early 1946 saw the wheels begin to turn in the first large-scale American effort to manufacture starch from sweet potatoes. More than $7,000,000 were expended in building and equipping the plant.

Behind the newly-moving wheels of the starch house at Clewiston stands the story of more than a decade of comprehensive preparation. Soils and sweet potatoes, men and processes had to be made ready.

The sweet potato has long been a famous food crop, notably in the southern states. The tubers grow in irregular sizes, and consumer preferences for a few uniform sizes have limited the proportion of saleable potatoes, since both the small and the large-sized ones had to be left behind as culls.

A small co-operative plant for making sweet-potato starch was established in 1934 at Laurel, Miss. The processes were based on earlier scientific work done in the Department of Agriculture. The technical cooperation of the Department continued as the Laurel operation developed through the years, and was broadened after the opening of the Regional Research Laboratory at New Orleans.

Clarence Bitting and his United States Sugar Corporation staff watched the Laurel experiment with active interest and before long with active cooperation. Dr. B. E. Bourne, the alert Barbados-born, Cornell-trained chief of the corporation's research staff, marshaled his resources to fit the sweet potato to the deep, rich muck soils of the Lake Okeechobee district, where the corporation's lands are located.

Variety selections looking to the highest possible yield of starch per acre, were made, which meant a high tonnage of sweet potatoes with a high content of starch. Before the time came to break ground for the starch house, the field research work had achieved experimental yields of as high as 39 tons to the acre, with starch yields reaching as high as 28 per cent. The tests gave hope that yields would average twenty tons with 20 per cent starch content.

Elsewhere a limiting economic factor in sweet-potato starch making had been found in the problem of storage. The tubers would not keep very long. Consequently the plant faced the costly prospect of standing idle except during the few months when the crop was being dug and the short time during which it could be stored. An alternative was to find a way of dehydrating or otherwise treating the potatoes so that the operating season might be extended. Either choice added materially to the cost of starch.

Frost sometimes strikes the Everglades but underground freezes do not. Consequently the storage problem was solved simply by leaving the crop in the ground until it was needed. Dr. Bourne, who never assumes that any practice is necessary merely because it is a practice, wondered whether sweet potatoes had to be planted in the spring. He tried planting them in October. The first carloads of newly-dug sweet potatoes that were processed through the starch house in January 1946 were from a crop that had been planted in October, 1944.

While Bourne and his scientific colleagues were improving varieties, surveying the insect and disease problems, and fitting varieties to the Everglades sunshine and muck, Bitting and his economic associates were trying to determine what the real market for starch might be. They were fully aware of the immense imports from the East Indies of the grades of starch with which they would be in direct competition. They knew, too, that larger quantities would inevitably enlarge the area of uses where either corn or root starches might be chosen. Bitting was impressed by the apparent fact that no matter how much starch had been poured into the American market, never had there seemed to be more starch than uses could be found for. He concluded that an efficient plant could convert Everglades' sweet potatoes into starch that could survive the competition.

III

Sweet potatoes come to the starch house in standard-gauge, open-topped railroad cars, which have been loaded from hoists at the various distant plantation sidings. Arrangements also permit unloading of trucks when potatoes are purchased from nearby growers. The railroad cars, after weighing, are pulled on to a tilting table, clamped tight, and their burden poured out into a soaking pit. Many of the roots are the size of a man's head. For a half-hour they lie quietly in the pit, until the adhering soil is wet throughout.

Then they are carried to tumbling washers, where they are bounced and sprayed until little except the potatoes is left. That, however, is not clean enough, so they pass through a brush-equipped washing machine which scrubs them behind the ears and between the toes, and sends them on to a storage bin. This is their last place of rest in the form of potatoes.

From the storage bin at the top of the starch house the tubers are fed into slicing machines which quickly reduce them to small strips. The strips in turn enter attrition grinders whose function it is to rupture the fibrous cells which contain the starch.

The pulp moves to low-speed centrifugals which throw off the natural waters, and on to primary screens through which about three-fourths of the recoverable starch will pass. The pulp which contains more starch is reground, rescreened and treated until maximum recovery is accomplished.

An innovation at the Clewiston starch house eliminates the extensive area of open settling tables through which it has been customary to pass the milky mixture while the solids were separated by gravity from the liquids. To handle the output of the Clewiston plant would have required almost acres of such equipment. The innovation is the utilization of high-speed centrifugals which, on the cream separator principle, accomplish the separation within a small area and a brief time.

The filtered starch cake at first contains about forty-five per cent moisture. After the final rotary drying this has been reduced to 10 per cent.

Up to this point the operation has been conducted in the "wet house," the largest of the five structures which comprise the entire plant. Starch is explosive. The rotary drying operation is therefore conducted in a separate building. In a third building the product is pulverized and separated. Also isolated are the final blending, preparation of orders to particular specifications, and bagging. All along the line samples are withdrawn for immediate examination in the laboratory, so that the character and quality of the product is under continuous check.

A by-product of the operation is a livestock feed made from the solids which do not emerge as starch. This feed is dried, made into pellets, and bagged.

The annual output of the starch house is scheduled to be seventy-five million pounds of high grade starches and thirty million pounds of livestock feed. The value of the output will be around five million dollars a year. Forty carloads of sweet potatoes will be required daily to be converted into ten carloads of starch and feed.

More than fifteen thousand acres will have to be harvested annually to supply the raw materials. The corporation will contract with other farmers in the area in addition to growing several thousand acres of its own. The estimated total of new jobs created by the enterprise is twenty-five hundred.

IV

The entire operation of the United States Sugar Corporation in the Everglades affords a fascinating view of a pioneer agriculture unfolding under the stimuli of modern science. The master philosophy of chemurgy is here creatively applied.

Cultivation of the Everglades at the outset was confronted by apparently insuperable problems. The surface is barely twenty feet above sea level, and the slope to the sea too slight to allow waters to drain off regularly from a basin with a fifty-five inch rainfall. Unwise drainage efforts in some areas had resulted in excessive drying of the peaty soil at some seasons, with fires and disastrous destruction the inevitable result. Eventually the Okeechobee Flood Control District was set up, and levees, locks and gates were constructed by United States Army Engineers. Now the lake, a circular body of some 730 square miles, is the central factor in a system of water control that is neither quite drainage nor quite irrigation. Water is pumped into the lake or out of it as conditions require. Embankments around sub-drainage districts, mole drainage through the fields, and lateral ditches every half-mile, permit a fairly accurate control of the water table in the soil.

The extensive lands of the United States Sugar Corporation are only part of the rich-soil district, but they are a large part. When Clarence Bitting assumed the management in 1931, the sugar cane harvest was three months long. The sugar house ran for ninety-two days. There was a terrific peak in labor requirement with a long interval when hardly a third of the peak number could be employed. Realizing the uneconomic nature of this situation, Bitting set himself the task of making Clewiston the center of what he likes to call an "agro-industrial" enterprise that would enjoy the stability of fairly even all-year employment. Today he is able to claim that 80 per cent of the peak number of employees may find work any day of the year.

This has been accomplished by a series of separate attacks. Research was one of the first. New varieties of cane were sought which could be harvested earlier or later, and cultural methods were directed to the same purpose. Now the sugar house runs 208 instead of 92 days, and the three-month harvest is a seven-month harvest. Mechanical methods, accelerated by labor costs and scarcities during the war years, tended also to reduce the height of the peak labor requirements.

The lemon grass enterprise made its contribution toward additional employment during the months not devoted to the cane harvest. The sweet-potato starch operation affords a long further step. Still another is the newly-begun production of ramie in cooperation with Newport Industries, Inc.

The Florida cattle population approaches two million head, with the demand within the state for milk and beef rising constantly above available local supplies. A limiting factor has been feedstuffs. Bitting has linked his expansion program with this situation. The spent lemon grass, mixed with molasses from the sugar house, adds to the cattle-feed resources of the state. The by-product feed from the starch house will add considerably more. Probably little of it will ever have to leave Florida to find a market. The sugar corporation has fenced about four thousand acres of the less productive land into pastures. Here purebred herds of Herefords, Angus, Shorthorns and Brahmans, and herds of feeding cattle, are maintained to study their response to improved grasses and practical feeding methods under Florida conditions.

Laid away in the files of Dr. Bourne's laboratories are basic data for adventures yet to be undertaken and warnings against plans that will not work out. Bourne's experimental gardens have grown a wide range of tropical and semi-tropical plants. He has a fair estimate prepared of the economic values of some that may be grown in future years and of others that will not be profitable subjects for a commercial venture. Red squill, for instance, one of the best of vegetable rat poisons, will grow as well there as in the North Africa areas from which most of it is imported. But it matures slowly, some four or five years elapsing between planting and harvest. The turnover, he thinks, is too slow for a profitable operation. Should anything go wrong with sweet potatoes as a starch crop, he would be ready to switch with comparatively little delay to arrowroot. That flourishes, and he has even bred varieties that excel in yield and sturdiness.

Peanuts and sesame, as sources of vegetable oils and more protein feeds, have been carefully explored and may some day blossom on the wide black acres, with an "oil house" added to the sugar and starch houses. With sugar and starch crops producing abundantly, should the national need for industrial alcohol justify a move to distilling operations, the corporation would not have to move far to be ready for that business.

Industrial water as well as agricultural water is an essential factor in a growing development such as that at Clewiston. The Corporation has lately constructed a remarkable modern water plant which has its source in Lake Okeechobee, and which purifies the huge amount of water required for the sugar and starch houses, and again purifies the waste waters after they have been used and returns them to the lake in a considerably cleaner state than they were found when first removed. The water system has a capacity equal to the needs of a city of 200,000 inhabitants.

Bagasse from the sugar house, the spent cane after the juices are extracted, returns to the boilers to serve as fuel. In time it may go into another plant for a higher purpose, the manufacture of wallboard.

From the sweet potatoes as they are polished up for the swift processes of the starch house is washed and removed a quantity of organic matter. From the extracted waters another organic residue remains. Even these liquids are processed. Screened to remove the rougher material, they are heated and conveyed to covered concrete digesters, where bacterial action sets in. Nearly a million feet of gas rises daily. It is recovered, piped to the power plant and consumed as fuel. The heavy solids which settle to the bottoms of the digester tanks are removed to the sandy, less fertile fields where they move toward other steps in the eternal economy of nature.

V

Many of those who have participated in the development of the chemurgic concept into practical applications to the land have been concerned with the preservation of the individual family unit in the agricultural economy. The independent family farm has been cherished by modern Jeffersonians not only as a guarantee of American political freedom but as a social ideal. Wherever applied chemurgy has increased the opportunities for income on the independent farm, as it has done in countless instances, the gain has been counted as a triumph with a plus value.

Obviously a chemurgic development on a huge scale under a single directing management, such as has taken place at

Clewiston, is no family farm enterprise. The United States Sugar Corporation runs a corporation farm and processes the agricultural output according to industrial practices.

Before the zealous devotee of the family farm, overlooking the innumerable increases in family farm incomes due to chemurgy, rises to complain that in this instance chemurgy has been adapted to the corporate structure, let him give consideration to pertinent circumstances surrounding this operation.

First of all, the obstacles nature has interposed between herself and a successful agriculture in the Everglades are formidable. The history of small individual failures and disappointments in the region would not be agreeable reading. Probably only a powerful and amply-financed company could have supported the private research, afforded the large-scale machinery, or developed the water-control methods which were all preliminary to any kind of profitable operation. Certainly only such a company could have conceived and created the starch house. Everglades agriculture even yet is distinctly pioneering, and pioneering is usually costly.

When the Clewiston operation was confined to the sugar business, before chemurgic diversification was introduced, the opportunities for labor were uncertain except for one-fourth of the year. Of interest at this point is a published statement by Mr. Bitting:

> . . . today work is available throughout the year to more than 80% of the peak number of employes. The work of the plantation employe is similar to the work of any other farmer, with some notable exceptions—the plantation employe works nine hours a day, six days a week, instead of from dawn to dark, seven days a week, and, by reason of the mechanical and power aids supplied by the employer, his work is less arduous. Employes are well paid. Those who turn out regularly for work, in addition to the perquisites listed hereinbefore (housing, education, medical care, hospitalization, fuel, ground for gardens, recreational

facilities, etc.), frequently have cash earnings in excess of the average annual cash income per farm in the United States for the years from 1933 to 1941, and often more than four times the average cash earnings of a third of such farms.

After describing the plantation villages around which each land unit of 3000 to 4000 acres centers, Mr. Bitting goes on to comment: "This size of operation permits the efficient use of costly equipment and utilizes to the greatest advantage the available manpower—the ideal or goal toward which agricultural engineering is directed. Through efficient use of both manpower and equipment, higher-than-average annual earnings of the worker are made possible. Life in such a village, with modern cottages, stores, church, school, first aid, hospitalization, entertainment and recreation readily available, yields more pleasant living and greater satisfactions than isolated existence in a one-room cabin, without glass or screens, on a patch of poor land."

The critic of this viewpoint may choose to insist that the farm worker may have another ideal in preference to either the isolated cabin or the company village. A comfortable home on land of his own still ranks first in the dreams of land workers and of those who philosophize about the family farm. Nevertheless, the realities of circumstance do not always permit achievement of the ideal; and probably one must add that there is no reason to suppose that the well-paid, village-housed, hired worker on the sugar corporation's lands may not be closer to owning a farm of his own than many of his brothers in the isolated cabins of the sharecropping regions.

The concern of chemurgy is with the economic utilization of all agricultural resources for the well-being of the human race. The idea is not restricted either to one nation or to one kind of farming. If intelligently applied by a corporation, chemurgy may assist in raising the standard of living of that corporation's employes and of its customers. Likewise, when profitably applied to the family farm the strength of that ideal institution can be made more secure.

Since the family farm has entered the discussion, a question recently raised by H. E. Babcock may well be quoted for the pertinence of the profound thinking behind it. Mr. Babcock, a member of the Board of Governors of the National Farm Chemurgic Council, is a New York state farmer who has long been a leader in agricultural cooperatives and in education, because of his unusual capacity for provocative thinking. His question is, "When we speak of the family farm, are we thinking of the family or of the farm?"

His tentative answer is that we ought to be thinking of the family; and that if the irresistible advances of mechanization, or other factors, make it necessary to prefer the family to the farm, then a sound arrangement to that end should be sought. He has suggested that one direction may be toward the independent, family-owned rural home convenient to the agricultural business operation which may or may not be fully owned by the family. Mr. Babcock would be the last to insist that this or any other ready answer can be final.

Indeed, there are not many final answers to human questions at this stage of history in the midyears of the twentieth century.

CHAPTER XI

Oils from the Sun

I

WHEN you washed your hands a few minutes ago, you used a bit of the vegetable oil that was an ingredient of the soap. When you ate your dinner, a vegetable oil was perhaps a part of the dressing for your salad; undoubtedly a vegetable oil had been used during the cooking of the meal; if any of the food had been preserved in a can, a vegetable oil was used during the coating of the steel sheet from which the can was made. Vegetable oil helped make the linoleum under the cook's feet. Without a vegetable oil the manufacture of your telephone and whatever electric motors you may depend on would be almost impossible. Vegetable oils are essential components of the paints which preserve, decorate and make more sanitary your home and furniture. Without vegetable oils your feminine associates would be deprived of the cold creams and other cosmetic preparations which they esteem as necessary to their self-satisfaction.

If one reflects that each day he repeats several of these uses, he will begin to become aware that during the course of a year of 365 days his consumption of vegetable oils is considerable. Multiply oneself by 140 million and the total quantity of the oils used in the United States becomes incomprehensible.

Farmers in the United States devote millions of acres to vegetable oil production as well as to crops that husbandry converts to the animal fats, butter, lard and tallow. Yet, after the oil is pressed from the cottonseed and the soybeans, from the flaxseed and corn germs, still the need has not been satisfied. Before the war some three thousand tons of oils and fats were being imported daily.

Here, obviously, the searcher for means to bring American agriculture into better balance finds an opportunity. Why should farmers be encouraged to grow more wheat and more cotton than America's consumers will buy when the same consumers are sending abroad for huge quantities of vegetable oils which the farmers might produce instead?

The answer to that query is by no means as simple as it looks. Yet the more one explores the details of vegetable oil production, the more he examines the details of the consumption, and the more he reflects upon the foreign policy aspects of the trade, the more likely he is to emerge with conviction that American agriculture ought to advance further into the oil-crops field. We do import a substantial portion of our surpluses.

Let's look at some of the details.

II

Within a temperature line that seldom wanders more than fifty or seventy-five miles from the Gulf Coast, on certain soils of Florida, Georgia, Alabama, Mississippi, Louisiana, and Texas, grows the tung tree. The isotherm of the weather maps loops far enough to let South Carolina set a few of the trees, and ten or a dozen growers have found a spot for them in California. Early in the spring blossoms of impressive beauty cluster on the twigs. In autumn, a harvest of nuts is collected. From the nuts is pressed an oil of superlative quality for its purposes. No other plant in the world yields an oil so desirable for paints, varnishes, and certain forms of insulation, where quickness of drying and toughness of surface are sought. Never has there been enough of it. The United States would gladly use twice as much tung oil as has ever been available.

The tung nut is a new crop in the United States. David Fairchild, the great plant explorer, about 1907 distributed a few trees that had been collected in China. The Chinese had long known the value of the oil. Spread on paper, it made their umbrellas shed water. The fame of their lacquers was indebted to tung oil. They had found scores of other values for it.

Few of Fairchild's trees survived, but the idea lived. Among those who became interested was B. F. Williamson, a businessman of national experience who had watched one of the surviving trees near Gainesville, Florida. Williamson invested in tung tree development and became an apostle of the crop, and over in Mississippi a former lumberman, Lamont Rowlands, began setting out trees. Both found that much had to be learned before commercial profits would be generous. Trees varied greatly in productivity. Little was known about fertility requirements. Equipment for processing the oil had to be found. But neither Williamson nor Rowlands could forget that tung is a superb oil and that tons of it could be sold if it could be produced at reasonable cost.

Consumption of tung oil in the United States before the war averaged 100 million pounds a year; domestic production barely touched five million pounds. Acreage, however, has risen steadily until probably 200,000 acres are now planted. The 1945 oil production reached 8,600,000 pounds and ten million pounds were expected in 1946. When trees now planted come into bearing, perhaps twice as much will be produced. That will still be no more than one-fifth of the normal pre-war domestic requirement.

China, gathering nuts from wild trees and pressing them by crude methods, has produced the rest of America's tung oil. Until very recently, little effort had been made there to establish cultivated orchards. Modern extraction machinery, if employed in China, as is expected, will enlarge the output and improve the quality, which now is inferior to that of tung oil produced in the U. S. Gulf states.

The efforts of Williamson, Rowlands and others are reflected in the increase of tung plantings from 350,000 trees in 1930 to more than twelve millions by 1940, with further expansion since. By the third year a well-selected, well-planted and well-cared-for acre in suitable soil yields from 72 to 144 pounds of oil. The yield goes up to ten or twelve hundred pounds by the seventh year, and thereafter should continue during the life of the trees at around 1500 pounds. These figures are on the high side, presuming the best of trees, soil and cultivation. The oil yield is several times that of flax. Normally the price is within three or four cents per pound of linseed oil.

Irresponsible promoters hurt the tung industry materially by selling to northern city buyers, who made no investigation beyond listening to glowing sales stories, small tracts with the promise of large profits. Frequently the land itself was unsuitable and the planting and cultivation inferior.

A major hazard to the most careful tung producer is freezing temperature at blooming time. Both the 1942 and 1943 crops were heavily reduced by frost damage, and experienced grove owners count on occasional small crops from this cause. From a national standpoint a large number of small plantings is viewed as desirable, since one grove may escape serious damage while another, nearby, may be fruitless. It has been observed, too, that single trees or very small plantings around homes, in fence rows and chicken runs, are often among the most productive.

The customary harvest method has been to pick up the nuts, which fall in November, after they have dried and cured on the ground. On the larger plantings the labor cost of this operation is high. Need for a more efficient harvesting method is recognized. A second need is for a good portable huller that will remove the hulls, which are a substantial proportion of the weight, at or close to the point of harvesting. A considerable cost in transportation would thus be reduced. A third need is for oil extraction processes which will remove more than the present 80 per cent of the oil which constitutes 18 to 22 per cent of the weight of the nuts. With a product worth 36 cents a pound during war time and greatly in demand for essential uses, the inefficiency of the available equipment was emphasized.

While substitutes for tung oil in some of its uses have been developed, the product is so nearly irreplaceable for many purposes that diminished demand appears unlikely. In the electrical industry, especially in insulation of wire, nothing better has been found. The expansion of electronics is expected to require quantities of tung. The production area is definitely limited to those lands where the soil is good enough and the temperatures mild enough at the right times. Tung is not likely to become over-produced. It can help diversify a part of the South and can strengthen the national security.

III

The oil of the flax seed is called linseed oil. The medieval Anglo-Saxons had a word for the flax plant: *lin*. Hence linen was their word for a cloth made of that plant. They also had a word for weaving: *fleax*. If these facts are not sufficiently confusing, mix them up a little more and you either will or will not understand clearly why we now call the plant flax, why we call the seed of the plant flax seed, and why we call the oil made from the flax seed linseed oil. The author himself is able to exhibit this feat of clarity only after a period of profound research in such obscure old tomes as Webster's New International Dictionary, India Paper Edition.

The favorite oil of the paint industry is linseed. There are those who say that if paints had been manufactured for a century from soybean oil, and linseed was now trying to obtain a foothold, the respective situations would be reversed; in other words, the industry is accustomed to linseed oil and hates to change. Whether or not this be true, linseed oil is full of virtue and makes good paint. Flax, therefore, is a chemurgic crop that is not only thoroughly accepted but indeed has long been established. Grown most extensively in the near Northwest states, it occupies lands which otherwise might likely be contributing still more wheat than is needed.

Since flax producers have gained an additional chemurgic market through sale of their straw for making cigarette and other fine papers, the crop is attracting additional interest. This was magnified during the war when the necessity for domestic linseed oil prompted a substantial subsidy.

Every continent contributes to the flaxseed supply. World production in 1935-39 averaged 135,800,000 bushels. Among the major acreages were: the United States, 1,451,000 (in 1943 it was up to 5,867,000); Argentina, 6,077,000; Europe, 1,300,000; Soviet Union, 5,055,000; India, 3,885,000.

The average yield in the United States during the same period was 7.6 bushels per acre while Argentina did better with 9.8. New Zealand, while reporting only about one thousand acres, had a 17-bushel per acre yield.

The United States never grows enough flax for the use of its own people. Pre-war years saw imports of linseed and linseed oil, largely from Argentina, amounting to from one to three times the home production, more often at the higher rate.

The trebled acreage under the war-price stimulant revealed that farmers will grow more flax when the effort is profitable enough. The stimulant in this situation was an artificially high price. Research may yet be able to make flax equally attractive by lowering costs of production, a procedure that is never unsound. Weeds are a major deterrent to good yields because the young flax plant does not smother them out. Chemical weed killers may help to reduce the weed competition, but it will be at the expense of another outlay and an additional operation. Flax yields suffer, too, from disease infections.

Plant breeders may be able to develop still-better-yielding strains. Improved new varieties recently have been released by the Minnesota and other state experiment stations. Harry H. Straus, head of the Ecusta Paper Company, is supporting extensive research in order to improve the attractiveness of flax as a crop which more good farmers will want to grow.

Old as flax is, man has yet to learn more things about it. If only enough were known to assure farmers that normally flax would be a little more profitable than wheat, the acreage might well expand enough to shrink very substantially the "surplus" of wheat.

IV

Cottonseed oil is nearly all consumed in foods. Peanut oil is sold as edible oil. The larger portion of the soybean oil output is consumed as food. While small portions are reluctantly taken internally on special occasions, the demand for the oil of the castor bean is definitely in the non-food, industrial category.

A remarkable plant, the castor bean yields a remarkable oil. "Castor oil has industrial possibilities that, if fully developed, might well create for it a demand rivalling that of any of our most widely-used industrial vegetable oils," one of the most eminent of American chemists has said.

The handsome, tropical-looking castor bean plant has grown as an ornamental in millions of American country dooryards. In all except a few of the coldest states it flourishes luxuriantly. Experience indicates that, if developed as a crop, the area between the corn and cotton belts might be most productive—states such as Kentucky, Tennessee, Arkansas and Oklahoma, with parts of Illinois, Missouri, Kansas and other adjoining areas, principally south of the thirty-eighth parallel. Many of the highest yields have been obtained on comparatively poor soils.

Among the highly esteemed peculiarities of castor oil are that unlike all other vegetable or animal oils it is not soluble in mineral oil; it is the only known oil that is soluble in alcohol; it will flow at extremely low temperatures. These characteristics, along with an unusual molecular structure, indicate a distinctive future for castor oil. Because of the vital necessity of the product for certain uses, few items were more rigidly apportioned by the War Production Board, while special measures were taken to arrange shipping to import all the Brazilian and Mexican beans that could be obtained. A small glimpse of the military uses of castor oil was afforded by J. Edmund Good, vice-president of the Woburn Degreasing Company, a major castor oil processor, when he spoke March 25, 1943, before the Ninth Chemurgic Conference at Chicago. Mr. Good said:

> Rather large quantities of castor oil are used for certain secret military purposes, principally by the Chemical Warfare Service. Because of its solubility in alcohol and its ability to flow at low temperatures, no substitute has been found for castor oil in hydraulic fluids. These hydraulic fluids are used in hydraulic brakes on all mobile and automotive equipment, such as jeeps, trucks, tanks, gun carriages and in the operation of bomb bay doors on our flying fortresses and other types of bombing planes and in the operation of turrets on planes and tanks and wherever movable turrets are required. Another reason why castor oil is essential in

hydraulic fluid is that it will not leak through the gaskets in the hydraulic system, as do other oils; nor does it gum. A somewhat similar fluid, also made from castor oil, alcohol and small quantities of other ingredients, is used in the recoil mechanisms of all kinds of cannon and high-powered rifles, of both large and small calibre, wherever a recoil mechanism is required.

I previously stated that castor oil in its natural state is not soluble in mineral oil. However, when partially dehydrated or when converted into other products it is miscible with mineral oil and therefore becomes a necessary part of the lubricating oil used in our aeroplanes, particularly those planes that fly to great heights where they encounter extremely low temperatures. A small addition of partially-dehydrated castor oil or other products made from castor oil will keep the lubricating oil liquid and free-flowing at these very low temperatures.

Up to a comparatively short time ago it was felt that parachutes and the bags that contain gun powder, which bags are inserted with the powder into the breeches of our big guns could be made from one substance—silk. However, parachutes and powder bags are now made from nylon and are satisfactory. To make nylon, considerable quanties of sebasic acid are required and sebasic acid is made from castor oil.

As the result of gasoline rationing we all know by this time that high-octane gasoline, fuel oil and other petroleum products are very essential for our war machines. These products are all made from crude mineral oil; and when crude oil comes out of the ground it contains a certain amount of water, up to as much as 15%, usually in the form of emulsions. In times past, the practice was to pump this crude oil into large tanks and let the water settle out, which operation might take days. Furthermore, not all the water was removed in this manner, because some of the emulsions refused to break. At the present time this settling is eliminated and the crude oil can be handled in minutes rather than in days. This comes about by the use of certain demulsifiers or emulsion breakers which are made from castor oil. These same emulsion breakers are also used in the oil wells to break the brine formations which cut down oil well production.

Practically all military equipment requires protective coatings to prevent destruction by rust and corrosion from the action of the elements. By protective coatings I mean paint or varnish or lacquer. These coatings must be hard and tough and water-resistant and in addition must be quick-drying. When a new house has been painted it really does not matter very much whether the paint dries in four hours or twelve hours or twenty-four or forty-eight hours, but it matters very materially if the protective coating, that is, the paint or varnish which is applied to articles made on production lines, does not dry very quickly. A whole assembly line or production line can be held up unless the protective coatings are quick-drying. . . . An entirely satisfactory product can be made from castor oil, to take the place of the now-unobtainable Chinawood (tung) oil. . . .

. . . sulphonated castor oil is required in the manufacture of textiles for uniforms, and is also used in the tanning and preservation of leather and for keeping it in usable condition.

Each of these numerous purposes for which castor oil was deemed a military essential has a civilian counterpart. In 1941 more than 150 million pounds disappeared, as the statisticians say, in the United States. Normally the imports are more than that by 50 million pounds. Among the 1941 forms of castor oil consumption were 44 million pounds for paint and varnish, two million pounds for soap, 1.3 million pounds for linoleum and oilcloth, and 760,000 pounds for printing inks.

A new product of the castor bean plant is an insecticide manufactured from the dehydrated leaves of certain strains. Made under the trade name of Spra-Kast, it has achieved a considerable market in Florida citrus groves and some demand in the Maine potato region. Even the people who make it do not pretend to understand fully the chemical composition nor why it performs as it does. But it kills several insects and appears also to act as a stimulant. After its application, the citrus leaves green up, and the potato plants grow faster. One guess is that the material may contain an enzyme, since the castor plant is known to develop more enzymes than it needs for its own growth. An enzyme has been defined as a "catalyst produced by living matter." No one has defined a catalyst much more precisely than can be accomplished by repeating the chemists' usual explanation to the layman that "a catalyst performs somewhat the function of a shotgun at a wedding."

Enzymes or not, the castor plant contains a deadly poison, ricinin, which kills insects. The plant itself is virtually exempt from entomological assaults. Presumably this is the insecticidal element, and perhaps the enzymes are the stimulant.

The stalk itself may be worth something. The bast fiber, which may be stripped from the top to the roots, is tough enough to make strong cordage. The rest of the stalk is easily digested into a good grade of cellulose. Among my possessions is a sheet of castor beanstalk paper made and autographed a few years ago by the members of Mel Handley's chemurgic school at Romayor, Texas.

The oil of the bean, however, is the primary value. Were the castor plant to become an important American crop, grown in substantial acreage for the bean's remarkable oil, means probably would be found to utilize the other values, too, on a commercial scale, if to do so were manifestly profitable.

The agriculture of the castor bean presents no mysteries and few difficulties. During the first half of the war, when the Nazi submarines were teaching tragic lessons to those who would keep the United States dependent on imports, the government authorities became frightened. Knowing that castor oil must be provided, even at the desperate cost of having it produced by American farmers, arrangements were made to build up a seed supply and stockpile.

Thirty-four farmers in Mason and Cass Counties, Illinois, kept cost accounts on their castor bean operations. They figure their average production cost at $20.39 an acre. They were paid $34.50 per acre for the output, and therefore had a profit of $14.11 an acre. The government war price may have been a little higher than a commercial price would be, proportionate to cost. Their yields, however, were only 600 pounds an acre. Experimental plantings in Illinois in previous years, perhaps with better quality of seed, generally yielded more than 800 pounds an acre; a great many produced 1000 to 1500 pounds, while a maximum of 1738 pounds was attained. Also to be taken into account is the fact that the adjustment of mechanical equipment for harvesting castor beans has not been perfected.

The sweep of the soybean was accelerated by the fact that all the necessary agricultural operations were easily and quickly mechanized. Machine equipment for planting, cultivating and harvesting was the same equipment used for other crops. Farmers were familiar with it. While experiments with the combine harvester, to bring in the castor bean crop, have been moderately successful, it is granted that the operation is not perfect. A hulling machine that works very well has been developed in Tennessee. No one who has given thoughtful attention to the problem appears to entertain serious doubt that the mechanical handling can be perfected. Naturally the dooryard plantings varied greatly in characteristics. A very little selection and breeding work has resulted in varieties that are not oversize, that are uniform in height, that retain the beans without shattering or uneven ripening, and that are, therefore, well adapted to mechanical harvesting.

Here, then, is a plant which has flourished for generations as an ornamental in American front yards and parks. Years ago, from the seventies to the nineties, it was in fact produced rather extensively as a field crop in Kansas and a few other states. The product is so useful, indeed, so necessary, that as many as 237,789,000 pounds have been imported in a single year (1940). Organic chemists are interested in it and are fascinated by its possibilities for forms of usefulness yet to be disclosed. Why, then, is it not among the important American field crops?

As much castor oil as is imported could easily enough be produced on a quarter of a million American acres. Those acres would not then be in competition with other acres producing corn or cotton.

The answer is simply that castor beans and oil can be imported cheaply. Whether they can actually be imported more cheaply than they could be grown, once the crop was established and its production efficiently mechanized, may be a question. Most of the imports come from Brazil. There the plant is not an annual, as here, but grows as a perennial, sometimes thirty feet high. Plants twenty feet tall may be found in south Florida. The beans are picked up from the ground by poorly paid natives. The economics of this procedure, as it applies not only to castor beans but to many other crops, is discussed in another chapter.

V

The vegetable oils divide broadly into two categories, the drying oils and the non-drying oils. A drying oil is one that has the capacity to absorb oxygen from the air. When incorporated into paint or varnish this chemical process is accompanied by a physical change from a liquid to a solid state, with the formation of a durable protective coating. The paint and varnish industries consume about three-fourths of the drying oils. Linoleum, oilcloth and printing inks take most of the remainder.

Linseed is the foremost of drying oils in extent of use. Estimates of 1941 consumption indicated that the relative quantities of drying oils consumed were:

Linseed, 670,000,000 pounds.
Tung, 49,000,000 pounds.

Soybean, 42,000,000 pounds.
Castor, 44,000,000 pounds.
Fish, 41,000,000 pounds.
Oiticica, 40,000,000 pounds.
Perilla, 5,000,000 pounds.

Normally the quantities of tung, castor and perilla would have been far larger, but wars and shipping conditions already were distorting the normal channels of commerce and closing off sources of supplies.

Tung is generally regarded as superior to all the other drying oils. It dries quickly, forms a tough coating, and possesses a high dielectric strength which suits it particularly well to insulation and to use in instruments through which heavy charges of electricity must move.

Castor oil in the raw state is not a good drying oil. However, when the oil is dehydrated the removal of a small amount of water appears to be accompanied by a rearrangement of the molecules. The product is a first-class drying oil which is regarded for many purposes as virtually the equal of tung oil. Dehydration of castor oil helped enormously during the war, when tung imports were shut off.

The oiticica oil mentioned in the list above is the product of a wild tree of the American tropics. Found principally in the Amazon, it comes from a nut which is sixty per cent fat of lard-like consistency—perhaps the only known solid oil with drying properties.

Perilla is a drying oil of excellent quality. Before the Japanese began their career of international gangsterism, imports from Manchuria in one year, 1936, amounted to 118 million pounds. Paper and fabrics may be waterproofed by perilla oil. Mixed with soybean oil it greatly improves that slow-drying oil for paint uses. Perilla is an annual plant which, as might be suspected because of its Manchurian origin, will also grow in the United States. An energetic and comprehensive research effort might well overcome its seed-shattering tendency and develop varieties suitable to machine production. The seeds are small, about the size of a pinhead, and tend to ripen unevenly and fall on the ground, from which they are irrecoverable. Japanese cultivators in Manchuria obtained twenty to thirty bushels of seed per acre, which yielded 400 to 700 pounds of oil. They valued the pressed cake very highly as a fertilizer for the mulberry trees from which the silkworms are fed.

Safflower is a promising oil crop for certain of the semi-arid regions and might find a place in the agriculture of such sections.

A Mexican plant, chia, yields a good drying oil. Chia is an annual. World flora, as a matter of fact, includes scores of species of plants, either now growing wild or presently cultivated, which have vegetable oil values. Alfalfa and clover seeds, if there were any to spare, would yield drying oils of high quality. Hardly enough of these are produced to meet the demand of farmers for seed. Tomato seeds, which are accumulated in large quantities at canneries, could be separated and pressed for an edible oil. Studies at an Indiana plant which cans 100,000 tons of tomatoes annually indicated that 125 tons of oil might be obtained from the seeds. Webster's New International Dictionary exhibits under oils a table of oil-yielding plants which fills nearly a full page of that highly informative work.

The drying oils are all in the class termed fixed oils by the botanist. The fixed oils, usually obtained by pressing a seed or given part of a plant, have been described as greasy fluids. The essential or volatile oils, usually obtained by distillation of the whole plant or any part of it, will not leave a greasy mark on paper.

Non-drying oils when exposed to air tend to become rancid. Cottonseed oil, of course, is a well known example. Coconut oil is another. Many of these are valued for their edible qualities—olive oil, sesame, sunflower, for example. Others, especially those which include lauric acid in their composition, are esteemed for making soap, as also are many animal fats. For soap-making the oils are combined with alkalis.

A non-drying oil of large importance in the United States is corn oil. When corn is ground for making starch, or for fermentation and distillation, the germs in the kernels are floated out. These, when pressed, yield the corn oil, most of which becomes a food ingredient.

Soybean oil (see Chapter VII) is an example of a versatile oil which may be broken into fractions, portions of the same batch being sold for drying oil, for edible purposes, and for making soap. The soap oils run low in the scale of economic value.

The extraction of the fixed vegetable oils may be accomplished by pressure or by solvent processes. Cottonseed oil is principally obtained by pressure, and at first so also was soybean oil. Solvent processes carry out a larger proportion of the oil in soybeans and several other oilseeds. The solvents are recovered and used again.

Incident to either pressure or solvent processes is the highly important by-product of meal or presscake, which from most of the seeds contains a high proportion of protein substances. This cake or meal is nearly all consumed as livestock feed. In fact, without it the livestock industry could not be maintained on the extensive scale that prevails in the United States. Exceptions to the rule are castor beans and tung nuts. Toxic elements in castor beans make it dangerous even to process the beans with machinery that is used for other seeds, because the other meals may become contaminated. The castor bean and tung nut meal do however have values as fertilizer and are returned to the soil for that purpose.

The vegetable-oil field is clearly one in which change will continue to prevail. That opportunities for expansion of American farm production are immense, seems obvious when one considers the enormous volume imported and takes into account the fact that many oils are interchangeable in use, that new economies in production and utilization are to be expected and shifts in both costs and values can constantly occur.

CHAPTER XII

Many a Mickle Makes a Muckle

I

LATE in 1940 a manufacturer of food seasonings reported that he was growing desperate over the shortage of sage. Europe's war had shut off the imports from Yugoslavia, Greece and Italy. His stocks on hand faced exhaustion. Unless the supply could be renewed, the next year's Thanksgiving turkeys might appear devoid of sage dressings and the sausage crop would certainly be destitute of the accustomed flavor.

This manufacturer thought that perhaps American farmers could be found who could grow sage of suitable quality. He had, in fact, worked out a plan which nearly guaranteed against loss a farmer who would attempt the new crop.

Interested in his idea, I wrote two paragraphs which were published in my personal column in *Farm Journal*:

> Farmers who like to adventure a little can do so this year with possible profit—or possible loss. Foreign supplies of a number of odds and ends of crops are growing scarce, and more may be impossible to get. So manufacturers who have heretofore been content to import their requirements are anxiously thinking about getting them grown in the United States.
>
> Sage is one such item. Ordinarily most of our commercial sage is imported from Dalmatia, a part of Jugoslavia. None can be had from there now, and more than one processor is wishing he had looked far enough ahead to keep American farmers interested. Sage, when properly cultivated, yields 1000 to 2000 pounds an acre, I am told, and a gross return of $200 an acre upwards may be possible. No one should undertake a crop such as this unless he has

suitable soil and is prepared to give it the best of attention. To any farmer who is seriously interested in trying from a half-acre to ten acres, I offer to pass his letter on to a manufacturer who says he is willing to contract for the crop.

Within a few weeks three thousand letters were in the manufacturer's hands. From among the applicants he selected farmers in several states from Georgia to Wisconsin. He chose tobacco growers by preference because the culture and harvesting of sage are similar to those of tobacco.

The manufacturer solved his problem. He had throughout the war a steady supply of American-grown sage of superior quality. Only the other day I was gratified to receive a letter of thanks from one of the Kentucky farmers. He and his neighbors were producing about 50,000 pounds of sage a year, and receiving for it forty cents a pound, a gross new business of $20,000.

The episode of the sage presents a fair sample of the human and economic implications that reside in many a situation, similar in character and greater or less in dimensions. The facts are simple, although minds will disagree as to their significance.

The average quantity of sage imported each year from 1929 to 1938 was 1,477,602 pounds. The average annual number of dollars paid out for the imports was $42,964. That was the entire amount of American money which, for sage, made its way into the country of production. For supplying our sage, the foreign sources were paid well under three cents a pound. By the time the buyers, dealers and exporters took out their shares, the Dalmatian and other peasants, one may be sure, did well if they received half that rate of pay for the actual work of growing and preserving the sage.

From three cents to forty cents a pound is a high jump in cost. Pity the suffering consumer! But obviously the fondest user of sage for seasoning could not possibly in a year eat enough to be more than barely conscious as to whether he was paying three cents or forty. If enough sage for 130 million people was bought for $42,964, the import price per capita was hardly more than one-third of a cent a year for each person. The outlay would still be less than a nickel each after the price rose thirteenfold.

Of these, one is a depression price abroad; the other is a war price at home. One is the price to a peasant who at such a rate of income will always be hopelessly a peasant with never enough money to buy as much as the poorest American would regard as the minimum necessities. The other is a price to an American farmer and means an American living standard not only for his family but for those who sell to him and serve him—and who can neither sell to nor serve the exploited Dalmatian peasant. Three-cent sage abroad will buy no American automobiles, refrigerators nor radios, nor even many packs of American cigarettes.

Inquiry naturally arises as to whether the foreign peasant-producer who laboriously raises a crop for which at most he can hope to receive a few cents for each day's toil, is being favored when his output is admitted thus cheaply into American markets. Would he not be better off if, deprived of this outlet, he turned to producing some other item which his own country could use and which would contribute something to elevating his own level of living? On the other hand, the American farmer who grows the product for an American price becomes an active customer of the American industrial laborer and a full participant in a national economy which, because of its prosperity, requires and can pay for large quantities of other kinds of materials which are welcome imports, since they do not compete with American farmers and workers, but instead constitute desirable additions to our living standards.

II

One and a half million pounds of sage is a very small item in an agriculture that elsewhere produces more than fifty billion pounds of wheat and around 170 billion pounds of corn. Nevertheless, to the farmer who can make a better living growing sage than raising corn, the difference favors sage.

Perhaps a hundred or so farmers could produce all the sage the country requires. However, there are other plants with comparable potentialities which in the aggregate can command the use of a formidable block of acres.

"United States Imports as Possible New Crops for Experimentation and Large Scale Domestic Cultivation" is the lengthy title of a booklet written in 1941 by Robert T. Willkie and Paul J. Kolachov of Joseph E. Seagram and Sons, Inc.

The authors of this booklet listed 131 items. The total amount spent by the United States to import these items per average year, 1929-1938, was $131,487,656; in other words, an average of a million dollars a year for each one. Most of the products listed were essential oils, medicinals, spices or like specialties. All of them are trifles, compared to the big crops. They would occupy few acres each, and find markets at present measured in no more than six digits. Yet each is important. Each product fulfills some human need or satisfies some human desire, else no one would go to the trouble of bringing it some thousands of miles from overseas. When Americans demand a product, American farmers may as well have the opportunity to produce it for the market within this country. If they do produce it, interruption of supply is prevented. Whatever acres it occupies are removed from producing another commodity which may tend to be in oversupply. Unless the new crop pays better it will not be grown; so, if it is grown, the growers will have more money than before to buy industrial products.

Coriander seed is definitely not a large-scale crop prospect. The average importation during the nineteen-thirties was valued at just under $60,000. The average annual shipments were 1,844,675 pounds. They came chiefly from Morocco, Hungary and the United Kingdom.

The oil extracted from coriander finds its way into a fairly long list of common products. The seed or oil flavors confections, canned foods, catsup, chili sauce, condiment sauces, and such alcoholic drinks as gins and cordials. It is used as a pickling agent. Salad dressings, spice extracts, tobaccos, perfumes and soaps may have a dash of coriander, while curry sauces generally find it a necessary ingredient.

The small quantity imported does not necessarily indicate the maximum potential of consumption. As Dr. Kolachov points out, "When . . . we are buying only what we actually need, and with just enough materials at hand for immediate demands, the door is closed to experimentation for wider use of the materials and for utilization of by-products. If we had a small surplus, we could experiment, and we might uncover more valuable facts like the discovery that an odor identical to that of the costly oil of rose can be made from coriander oil." The huge expansion of soybean production, made possible as research constantly disclosed uses for additional volume, is appropriately cited as an illustration of how demand for a plant material once required sparingly or not at all in an economy, may multiply to large-scale dimensions.

III

Sporadic efforts have been made for a very long time to establish new plants in American soils. The early colonists brought seeds and bulbs and roots with them and thus, of course, came wheat and cotton and, indeed, most of the present cultivated crops. Among the leading Revolutionary fathers were farmers who, like Jefferson and Washington, obtained new seeds and new farming ideas from their correspondents abroad. Diplomatic and other national emissaries frequently sent plant materials home. Far-sailing ship captains occasionally brought things back for their gardens or the gardens of their friends. Immigrants have at times brought in seeds of their favorite plants. During the first part of the present century the Department of Agriculture sent plant-explorers into the Old World after better varieties of fruits, cereals and grasses. The profits from those adventures have many times repaid the costs.

Complete or partial failure has attended such overseas transplantations more frequently than success. If the conditions of soil, moisture, sun, season and other requisites are satisfactory, no plant will refuse to grow merely because an unfamiliar flag waves within its view. Plants are not nationalistic, but they do insist upon surroundings and treatment similar in all other respects to those to which their ancestors were accustomed. The removals, probably more often than not, have been made by persons not sufficiently observant to note the exact requirements of the plant in its native surroundings. Frequently the materials have gone into the hands of persons who were interested but uninformed about the plants' natural environment and cultural demands. The failures have not necessarily proved that the plant refused to grow profitably but rather that the grower may have been improperly located or inadequately informed.

Commercial efforts which have failed in past experiences likewise do not necessarily prove that a given plant cannot be cultivated with profit in the future. New knowledge of soils, fertilizers, cultivation and other factors is available which was not applied in the past. Better-adapted equipment now at hand may make the difference between a former failure and a future success.

A wide range of quality and yield per acre may result directly from a difference in seed strains. Dr. Kolachov remarks that coriander seed from Russia and Hungary yields four times as much of the essential oil as the seed from the Moroccan strains and ten times as much as the East Indian varieties. The experimental grower who starts with Moroccan seed might naturally conclude that the crop is not worth while, when, if he knows where to obtain the highest-yielding strains, his effort might return satisfactory profits. Not only is gross yield an important factor; quality of product and adaptability for the intended use may govern the price. Here, again, the plant geneticist may make his contribution through selection, breeding, and fixing of the desirable plant characteristics.

Experimental tracts of coriander grown in Kentucky by the Seagram Company produced yields of 1100 pounds per acre. Local areas in more than half of the 48 states, where conditions are probably suitable for this particular crop, are indicated by Dr. Kolachov.

The ten-year-average imports of caraway seed were 5,469,100 pounds, valued per year at $370,413. Netherlands and Russia were the chief sources. The seed is best known as an excrescence applied for incomprehensible reasons by some bakers to their rolls and buns. Medical applications include treatment of flatulence and as a stomach tonic. Makers of soaps, gins and perfumes sometimes use it as a flavoring agent. Local areas in some ten states are believed promising for experiments in caraway cultivation that might result in its establishment as a permanent crop.

A few further examples from the Willkie-Kolachov list:

Angelica root, brought from Germany at the rate of $26,871 a year for only 33,253 pounds; used in tonics and candy, in rectification of alcohol and distilled liquors, as an essential oil in bitters and perfumes.

Canary seed, of which more than half a million dollars worth is annually brought from Argentina and Turkey for canary food. Varieties called canary grass have lately been introduced into American pasture and hay mixtures. Birdseed varieties could no doubt be easily enough adapted.

Menthol, a product of peppermint plants, imported from China and Japan at the rate of $864,412 annually during the 1929-38 period.

Mustard seed, from Asia and Europe, $561,037 worth a year.

Paprika, a condiment from Hungary, Spain, Czechoslovakia and Bulgaria, which countries received $763,649 a year. During the late war paprika was very successfully grown in Washington and Louisiana and, I believe, also in South Carolina, by men who were familiar with its cultivation abroad.

Psyllium seed, $310,669 annual imports from France and British India, used not only as a cathartic but also in certain processes of sizing silk, and in the manufacture of paper and printing fabrics.

Rapeseed and rapeseed oil are brought from several temperate-zone countries. The annual payments for the various forms of oil and seed averaged $1,675,160. The American uses of rapeseed oil are principally for lubricants, for heat treatment of steel, and for the manufacture of rubber substitutes. The rise of synthetic rubber has increased the demand. Germans process it for a salad oil. Before petroleum became well known, rapeseed oil was produced extensively as an illuminant and may still be so used in a few primitive areas. The plant grows readily in much of the United States. It is commonly sown as a late-season hog or sheep pasture crop. Domestic production of the seed for oil may possibly be largely a matter of engineering economical harvesting equipment, and of encouragement. Some war-time production was instituted in Montana.

From central Europe the annual imports of stramonium averaged $322,695 during the 1929-38 decade, or somewhat more than a dollar for each of the 307,729 pounds. The use is medical, with particular application to asthmatic conditions. Stramonium is nothing more nor less than a Latin name for the jimson (Jamestown) weed that flourishes uninvited in a million American hoglots.

IV

Among the plants listed above are several which have adapted themselves to United States soils; some, like stramonium, grow so well as to be classed as a nuisance. For their products a substantial American demand pays enough money to make the purchases from foreign producers, to pay the shipping charges and importers' profits. Why, then, are not these proven items, at least, providing income to American farmers?

The usual, though not always the correct, explanation is labor cost. The production, harvest or preparation of the desired part of the plant may call for a larger expenditure of patient human hours than Americans are willing to spend at such work for the returns offered.

Corollary explanations are that differences in quality favor the imported products; that until equipment is developed to do more of the required specialized work mechanically the crop cannot be made to pay; that because the total requirements are so small, no one bothers to design the equipment.

The actual explanation, in at least a few instances, is quite another story. The castor bean, mentioned in a preceding chapter, will serve as a case in point. Castor beans grow both in wild or cultivated states overseas. In the principal source country, Brazil, the wild crop is harvested by natives who simply pick up the fruits from the ground. Cultivated and growing vigorously as an ornament in two-thirds of the United

States, tests have indicated that the plant can easily be made a successful crop so far as production and harvesting are concerned. Basic equipment problems do not appear to be too difficult. Quite a little seed selection has been practiced. Good varieties are known and the soil types on which best results can be obtained have been identified. The quantity used is not trivial; imports, even during the nineteen-thirties, approached three million dollars' worth a year. The present uses are many, and top-rank chemists have predicted that the utilizations can be hugely expanded.

Everything in this instance would appear favorable to allowing the castor bean crop to obtain a commercial foothold on American farms. But virtually all the American processors of this item depend for their regular supplies upon certain importers. Life for the importers is fairly simple. They do not deal with the natives who collect the crop. They buy only from brokers at a few ports. An occasional pleasant trip to the producing country, a little polite palaver with the foreign factors, and the price is settled. Whatever it is, the natives have to take it. There is no dealing with farmers, no bargaining with cooperatives or informed American assemblers. And there is, conveniently, no tariff on the product.

Consequently, all efforts to interest the importers in buying from American farmers until recently have been unsuccessful. The gentlemen have had a good thing and they know it. Processors can hardly afford to reach for the small amounts so far offered by domestic producers, because they may find themselves deprived from their regular source, and most of them require fairly large quantities. Farmers can not well afford to venture extensively into a business which requires a little special equipment when they have no firm offer of price and, indeed, have no reason to expect any encouragement. Since the processor can not turn to domestic production without risk, and farmers have no assurance of a buyer, and since the importer has every incentive to avert establishment of domestic sources, the old procedure goes on year after year. When war interrupts shipping, the country takes its chances on shortage, while the industrial consumers scurry around, appealing for farmers to grow enough to see them through.

There are those who believe that a constant drain upon the public treasury for subsidies of various kinds to support overextended crops, such as wheat and cotton, has no long-time justification. Far more wheat and cotton are grown than the nation needs or can find good markets to buy. They think a more reasonable course would be to occupy more acres with other crops, so that fewer acres would remain in production of the surplus products. They are confident that the American citizen in his dual capacity of consumer and taxpayer would benefit even if he had to pay a little more for some of the products that could be substituted but in consequence could escape being taxed for such extensive subsidies. They point to the fact that once American producers, agricultural or industrial, undertake to grow or manufacture a commodity they invariably find cheaper ways to accomplish their purpose. In the long run, they are confident, the national economy would be ahead if a much larger variety of crops were grown on American farms.

Some of the new crops could provide products which are now imported with little actual benefit to the foreign producers. Others might be new in the larger sense that they would supply items not heretofore included in the standard of living.

A few of those commonly imported have been mentioned. In the entire flora of the earth are countless species yet to be examined for their potential economic values.

V

The extraordinary variety of useful purposes for which bamboo serves the natives of the Orient never fails to interest visitors to Asia. A few of those who have seen bamboo in temperate Japan or at altitudes of 10,000 feet in the Himalayas have wondered why the plant is not grown in the United States. Some of those few have found that it will grow here.

Farmers in Jasper County, Texas, have been picking up a few hundred dollars a year by selling bamboo fishing poles to Houston dealers. The roots were planted there in the mid-thirties and have flourished very well indeed.

E. A. McIlhenny, the versatile giant of Avery Island, Louisiana, has grown bamboo for a long time. (McIlhenny manufactures a famous tabasco sauce. From the tabasco factory a few minutes walk takes one to the entrance of an 800-feet-deep salt mine). He has for many years experimented with warm-climate plants on his Gulf Coast lands. From his bamboo a very good white paper has been made by Arthur D. Little & Co., noted research laboratories. The Herty Foundation at Savannah, Georgia, has also been looking at the paper possibilities in bamboo. Since yields of 70 to 100 tons of dry stalks per acre every three years are obtained from some of the Chinese varieties, Mr. McIlhenny agrees with those who believe bamboo might eventually become a prolific source of cellulose. Its fast growth might make it productive of even more cellulose per acre than the Southern pine. Pine 20 to 28 years old yields about 18 tons of pulp per acre; Canadian spruce 80 years old, about the same amount. Six-year-old bamboo, McIlhenny says, will produce more than that and then repeat the yield every year.

Near Savannah, more than sixty varieties of bamboo grow in the Plant Introduction Garden of the Department of Agriculture. Some varieties grow to a height of 60 feet in a single season. In the tropics bamboos sometimes reach 120 feet. While most varieties are tender, temperatures as cold as three to five degrees below zero are withstood by a few of the tougher kinds.

For porch furniture, fishing poles, sports equipment, radio antennae, there is a substantial market in the United States for bamboo. Should new sources ever be required, as is possible with the steadily growing consumption of paper and plastics, bamboo might conceivably be made an important crop in the Southern states. The famous British scientist, Alfred Russell Wallace, wrote that "it is one of the most wonderful and beautiful productions of the tropics, and one of Nature's most valuable gifts to uncivilized man."

Civilized man may find new uses for it, too.

VI

Some four million species of insects share the earth with men. No small numbers of them are in conflict with the purposes of the human species. They bite and infest man. They annoy his animals and fowls and impair their productivity. They eat his crops, destroy his seeds, and may even chew up his houses.

Wherever the natural balance of nature has been destroyed, one or more species of insects appears to discover a rare opportunity for prosperity. Consequently, when man clears a section of the earth's surface and devotes it largely to production of some single crops, insects of which he may never before have heard tend to move in to multiply on the bounty his arrangements have so abundantly provided.

The contest with the insects is a difficult one. These six-legged opponents are numerous and they are small. Their ability to hide in inconvenient locations, the peculiar life cycles during which a single species in the course of weeks may be eggs, pupae, worms, or winged creatures, all create multiple complications. The shortness of their life cycles permits incredible increase in numbers.

To attain any degree of equality in the contest, man is compelled to attempt wholesale warfare. He fills the air with toxic sprays of liquid or dusts, hoping that enough will adhere to his precious crops so that the enemy can not escape them. Poisons are his primary weapons, poisons that the insects will eat. He must take care that his poisons, if dangerous to animals or to his fellow human beings, do not kill them also, or do not accomplish other unintended devastations. He has, therefore, for years been conducting an unremitting search for toxic substances that will enable him to gain some advantage over his principal rival for possession of the earth and all its goodness.

Neither the mineral world nor chemical search through organic compounds have found insecticidal materials that for general use are superior to two elements found in growing plants. One is rotenone. The other is pyrethrin.

Neither of these is harmful to man or animals (as so far are DDT and other recent discoveries). Included in sprays and dusts, they may be spread freely without concern, except as beneficial species of insects may be hurt.

Rotenone is an ingredient of the roots of a number of tropical plants of the bean family, principally Derris from Malayan regions, and Lonchocarpus from the Amazon basin. At least sixty-seven species of these plants are known to contain rotenone in some quantity. The toxic nature of these plants has long been known to natives of the regions to which they are indigenous, and preparations are still used by natives as an easy way to catch fish by poisoning the waters. Numerous native names are applied to the plants.

The United States imported, in 1939, a total of $322,257 worth of rotenone-bearing roots from British Malaya, Netherlands Indies, the Philippines and French Indochina. Another $290,653 worth came from Brazil, Peru and Venezuela. This amounted to $612,910 for 5,908,710 pounds of the roots.

No rotenone-producing plant is grown commercially within the United States. However, down in east Texas and in Arkansas a perennial weed which farmers have fought and fervently called "devil's shoestring" has been found to contain rotenone in fair quantity. Certain strains assay as much as five per cent, which compares favorably with tropical proportions of the element. Botanically the weed is *Tephrosia virginiana*. Possibilities for its commercial cultivation have been tentatively explored, but no earnest effort has been made and none which has yielded enough data to indicate how difficult would be the performance of its promise.

Pyrethrum, however, has been extensively investigated. This is the plant that yields pyrethrin, the lethal element in many well-known commercial insect sprays. It's a daisy, closely related to the painted daisy commonly known to flower gardeners. The principal sources of supply, since pyrethrum has become a commercial product, have been Japan, Dalmatia, and in later years Kenya in eastern Africa. The flowers, picked after opening, contain the poison.

As long ago as 1927 the manufacturers of Flit launched an investigation of domestic pyrethrum production. R. E. Culbertson, who was in charge, established plantings and experimental stations under various auspices in nearly every state. The studies revealed that the plant grows readily in several areas and yields flowers as abundantly and of as high toxicity as the crop does elsewhere in the world. From 300 to 800 pounds of flowers per acre have been collected. The daisy is perennial. No flowers are harvested the first year, but production continues for six or seven years. The Fontana Farms Company in California has reported 1041 pounds of flowers from the first harvest of one and one-fourth acres.

Normal imports of pyrethrum exceeded ten million pounds and are valued, abroad, at more than one and a half million dollars.

The principal difficulty confronting economic American production has been found in harvesting. Foreign producers with cheap labor have been willing to pick the flowers by hand. Active interest in the pyrethrum possibilities, however, finally led to efforts, which have been pronounced successful, to develop a mechanical harvester which cuts the whole plant and strips off the flowers. War interfered with plans to manufacture the machine. Pyrethrum, nevertheless, is a fairly good prospect for attaining a firm place as one of the important minor crops in the agriculture of the two or three regions which seem best adapted to handle it.

VII

Arizona farmers are producing on their irrigated fields a new crop called guar. This legume found itself a place in American agriculture and industry by no intent of its own. No one started out with the idea of establishing guar as a crop.

What happened was that an industry started out with a set of specifications. A search was conducted to determine whether there might not be, somewhere in the world, a plant with the characteristics necessary to meet these industrial specifications. The plant was found in India, and it happened to be guar. Botanically, guar is known as *Cyamopsis proraloides* or *Cyamopsis tetragonaloba.*

Expert papermakers had long realized that their mechanical methods were not getting the most out of the fibers of cellulose. They were aware that something was needed to produce papers of higher porosity, formation and strength. Yet the mechanical methods of hydration made these desirable properties incompatible one with another. They were looking for a way to make papers which would possess, as Ben W. Rowland of the Institute of Paper Chemistry has expressed the need, "higher opacity, better compressibility for better printing, lower dimensional change in fluctuating humidity, less curl and cockle, and, where desired, a higher content of fillers and filler pulps." As the paper men had said, they needed a way to "pour hydration out of a barrel."

Earlier knowledge had indicated that the desired substance would have to possess some mucilaginous qualities. Locust bean flour, obtained from the carob fruit, the St. John's bread of Mediterranean countries, had provided a clue. This has been used in very recent years as a source of mannogalactan mucilage—mannogalactans having been described as first cousins of both starch and cellulose. A domestic source whose quality could be controlled seemed more desirable than dependence upon the locust trees of the Mediterranean.

Since legume seeds appeared to offer the likeliest prospect, a study of all such seeds, cultivated and wild, domestic and foreign, was launched. The Institute of Paper Chemistry led the search. Twenty-five paper manufacturing companies eventually participated in backing the undertaking. General Mills, Inc., entered the picture, since the seed would have to be milled, the mucilage products separated, and provision made to take advantage of any possible by-products.

Before the investigation had found a suitable plant, the U. S. Soil Conservation Service and the University of Arizona were found to be hunting a new legume suitable for enriching the soils of the Southwest. So the industrial group and the agricultural inquirers joined hands, thinking they might find a legume that would serve both their purposes. Seeds from scores of trees, shrubs and plants, perennial and annual, were investigated. Even botanical seed collections were invaded. Eventually it was agreed that guar was worthy of serious trial.

The first few hundred acres were planted in 1943. Guar had a tough time that year. The weather was severely unsuitable, insects were worse than usual, and an army bomber chose the best of all the fields as a place for a crash. Nevertheless more than a hundred tons of seed were harvested and shipped to Minneapolis for milling. The results were good enough, when small experimental quantities of guar mucilage were tested in various paper mills, to encourage more extensive plantings in 1944 and thereafter.

Subsequent experience appears to indicate that guar is the answer to the paper man's prayer for hydration that he can pour out of a barrel. Nor is the paper industry the only prospective customer. Guar mucilage will serve for sizing textiles, for use in pharmaceuticals, foods, leather, synthetic rubber processing and other fields yet to be explored.

How extensively guar will be grown will depend, of course, upon the demand. The fact that it fits a farm need for a soil-improving crop in the southwest gives it a head start. The soybean had that, among many other early advantages. Probably no one yet knows over how large a range of soils the crop will be adaptable. The yield, incidentally, has run from 1000 to 1300 pounds per acre, which compares favorably with the early yields experienced with soybeans. A guaranteed price to farmers has been maintained to obtain the desired production.

The circumstances which had led to the establishment of guar are unusual, if not unique. An industry, fortunately well organized to sustain research for itself, realized a need and suspected that some crop might fill the need. When the crop, a product of another continent, was discovered, the industry did not exult over the prospect of having its supply produced by the cheapest labor on earth, but brought the development to the United States.

The needs for new products of crops, recognized and still unrecognized, are numerous enough. Only now and then is any industry so situated as to be able, as was the paper industry, to follow the need to the discovery of a way to supply it. For that reason, new crop research supported by public funds can be fully justified.

VIII

At lunch one day several years ago I asked Dr. Firman E. Bear, the world-famous soil and fertility authority, now at Rutgers University, to name the specifications of the perfect crop from a farmer's standpoint. These were his specifications for such a crop:

1. It should hold the soil from erosion.
2. Its growth should improve the fertility of the soil.
3. It should be economical to plant, cultivate and harvest.
4. It should yield a profitable annual harvest.

Dr. Bear's first specification clearly called for a tree, shrub or grass, since no other types of plants so effectively hold the soil from removal by water or wind. The second specification demanded a legume, since only the legumes deposit any substantial addition to the fertility of the soil in which they grow. The third specification also indicated a perennial, such as a tree or shrub, for which annual plowing and continuous cultivation would not be needed.

The only plant I could think of which met these three requirements was the locust, which is a tree, a legume, and of course a perennial. This, then, presented the problem of finding sufficient values in the locust pod and bean to meet the fourth specification for a profitable annual harvest.

I was aware only that the Mediterranean carob, mentioned a few pages above, was sometimes eaten. In fact, I had occasionally picked one up in pushcart markets and chewed it with a momentary pleasure from its sweetness. I knew also that livestock would eat it, and presumably derived nourishment from the sugars and other ingredients.

Shortly afterward in a dining car visit with a friend who heads the laboratories of a large pharmaceutical manufacturing company I related the conversation with Dr. Bear. From him I learned that for some years locust beans had been harvested in central Europe and shipped to England, where a jelly was extracted; no doubt a form of the mannogalactan mucilage. This jelly was imported by pharmaceutical makers to be used as a carrier for drugs which have to be divided into minute quantities for individual doses.

J. Russell Smith, the geographer and tree crop student, and John W. Hershey, the Pennsylvania nut tree specialist, have combed the country for locust trees with beans of high sugar content. Their idea has been to find a strain that will produce a heavy crop of palatable livestock feed, particularly for poor hillside soils.

Whether any form of the locust tree will ever be perfected to meet all four of Dr. Bear's specifications I should hesitate to try to predict. The evident substantial market for guar might indicate that this humble and ancient tree deserves more serious investigation than it has yet received.

IX

Dr. Boris Berkman had a good job, for a young fellow, in Moscow in 1920. Educated in two or three mid-European universities, he had been made director of the Pasteur station in the Russian capital. That was a respectable position. But turbulent Russia did not promise the kind of a future preferred by an individualist.

He didn't resign his job. That he couldn't do, under the customs of the land. So he did what he could. By walking and hiding he made his way across the Polish border. Once in Warsaw, a harder task confronted him. That was to talk the American consul into giving him a visa when seven or eight hundred other applicants were ahead of him. He was sufficiently persuasive, and before long had set himself up in North Chicago as a diagnostician.

His practice within a few years was yielding money enough that he could take occasional vacations. The sand dunes along the southern and eastern shores of Lake Michigan interested him. He watched the winds move heaps of sand from one location to another. In the papers he read about the menace of soil erosion.

Why a Russian-born, North Chicago diagnostician should have decided to worry about soil erosion remains to be explained. Perhaps he wished to make some return to the country which had given him the opportunity to prosper. At any rate, the erosion problem did interest him, and he set himself to thinking about it. He reasoned that soils could be held in place by a plant that has deep and widespread roots. Such a plant grew among the sand dunes. It was milkweed, and wherever it grew the sands stayed put. Its roots were deep and spread themselves far. Being a perennial, its roots were there all the time.

Berkman decided that all he needed to do to solve the erosion problem was to find profitable uses for milkweed so that farmers would have reason to cultivate instead of to eradicate it.

"I knew," Dr. Berkman has said, "that Thomas A. Edison had tried to produce rubber from milkweed. A yield of about four per cent can be obtained. But Edison's efforts had not made the milkweed a rubber crop, and I didn't believe I was any smarter than Mr. Edison."

Berkman examined the fiber of the stalks, a long, tough bast fiber that is hard to break. Might be something there. He noted the floss in the pods. Here was a device which nature had developed for her single main purpose of reproduction. When the pods burst open in fall, the silky fibers of floss loosened into the wind and bore to new locations the seeds to which they were fastened.

The small fibers looked interesting. He put them under his microscope. He checked the literature, which confirmed what he had seen. Each one of the tiny fibers, each smaller than a hair, was a hollow tube, closed at the end. An air space enclosed in cellulose, such as that, might be valuable for use as insulation.

Further study revealed the interesting fact that each tiny fiber was completely covered with a microscopic coating of wax. When the fluff with its burden of seed had fallen on the water he noted that it never appeared to sink. He collected a large wad of the floss and placed it in a large bowl of water. It held up an orange. Further tests indicated a remarkable buoyancy. A pound of floss would sustain fifty pounds of weight on the water. That being the case, three or four pounds would sustain a man!

By this time war was imminent, war in the sky and war on the sea as well as on the land. From his observations on insulating quality and buoyancy Berkman evolved the idea of a quilted flying suit lined with four pounds of milkweed floss. Such a suit, he believed, would keep an aviator as warm in the subzero temperatures of the stratosphere as the awkward electrically-heated flying suits, and would be more convenient. Then, if the flyer had the misfortune to be plunged into the sea, the suit would keep him afloat for a hundred hours or more. He made such a suit and took it to the United States Navy.

Meanwhile Berkman had learned that the commercial product which most nearly resembled his milkweed floss was kapok from Java. The East Indies, soon after Pearl Harbor and Singapore, were in the hands of the Japanese, who would be selling no kapok to the United States for some years to come. And the life preservers, the "Mae West" jackets, upon which the lives of millions of our men at sea might depend, were stuffed with kapok!

Berkman hurried to Washington. He rather expected that the army and navy authorities would jump at the chance to obtain a domestic supply of a fiber that would meet the immense need for lifejackets.

But no one in Washington jumped. In fact, hardly anyone even budged. Berkman became a man with a briefcase and a mission.

To anyone behind a desk who would listen, he patiently explained the importance of milkweed toward winning the war. He told them how he had invented the necessary machinery to process the fiber. Nature, he had discovered, opened the pods by dehydrating them to a certain point. He did the same thing. When the fibers were thus released, the seeds were still attached, so he had devised a "gin." A strong blast of air drove the floss through screens which would not pass the seeds. Then the pure floss could be sacked or baled, ready for shipment.

Lieutenants and commanders, captains and majors and colonels, some generals and admirals listened to the insistent, voluble doctor and passed him on to some one else. He was not always polite about the runaround. The experts were called in. They could turn him away, but they could not seem to trip him. He seemed to have thought of everything. Eventually he persuaded them to make tests in their own laboratories. Those tests confirmed his assertions.

From Chicago to Washington and back is an expensive journey. Dr. Berkman had made twenty-one round trips. He had taken down his sign as a doctor, for he could not diagnose the ailments of North Chicago while traveling to Washington. He had been prosperous, but not rich; the possibility of going broke had to be considered.

Then one day the Army and Navy sent a request to the War Production Board. The War Production Board passed requests to the Reconstruction Finance Corporation and to the Department of Agriculture. The Department of Agriculture sent directions to the Commodity Credit Corporation. A stockpile of nine million pounds of milkweed floss had been ordered to be acquired in the next three years.

Between trips to Washington Dr. Berkman, with some interested friends, had set up a small factory at Petoskey, Michigan. In this region, he had learned, milkweed grew in wild abundance. The factory was equipped to dry the pods so they would open, to blow the floss against the screens which separated it from the seeds, and to bale the floss. Farmers and their families had been paid to collect the wild pods.

The government agencies enlarged the factory. They appealed to schools and to Boy Scouts all over the milkweed-growing states to collect the pods, for which they paid twenty cents a bag. Highway departments were asked not to cut the milkweeds along the roads when they mowed the rights-of-way. During the 1944 season enough pods were collected to produce 1,500,000 pounds of floss.

So it came about that a common weed, abundant in a million American fence corners and pastures, proved able to supply the qualities for which the nation had been sending halfway around the world to obtain in kapok from Java. The Navy never announced how much of the floss eventually was used in life preservers, but milkweed life preservers were made in large numbers. The story of one service man came to Berkman's ears. Dumped into the Pacific and eventually rescued, he became curious to know just what was in the "Mae West" jacket that had kept him alive long enough for the rescuers to discover him. He took it apart and found that the buoyant material was milkweed floss.

At the war's end Berkman and his associates puchased the greatly expanded Petoskey facilities back from the government. Markets for the floss in pillows, toys and similar objects had been obtained.

The seeds, of which more than 2,500,000 pounds had been accumulated, were to be made into oil which is suitable for paints, varnishes and alkyd resins. Berkman's associates dreamed of an oil plant, and of a plant for extracting the wax which is present in the pod shells.

Will milkweed then become a cultivated crop? That question is still unanswered. The Soil Conservation Service has established a number of experiments in different places to determine the value of the plant as a soil-holder under varying conditions. The conclusions have not been announced and perhaps have not yet been arrived at. The studies of the agriculture of the plant—when to sow, how to cultivate and other matters farmers would need to know—have as yet been scanty. Probably further commercial development will be necessary to find out whether the market will justify prices that will be interesting to farmers. The fact that the weed grows prolifically on poor lands, especially in such lands as comprise the cutover belt of the Great Lakes states, where a new crop is needed, is a base for hope that the commercialization process will be successful.

Berkman himself is only casually interested in the business beyond the point of getting it established. He has arranged for other hands to attend to that. For himself he sees another great research task which he believes may lead to still greater human benefits. He has discovered a new process for extracting chlorophyll from green plants; and chlorophyll, he is convinced, can become a commodity of exceeding importance.

Whatever the future of milkweed itself, vastly more is known about this one plant among nature's three hundred thousand species than had been suspected before Berkman set to work upon it. The experience has already been so successful that it may well stimulate similar exploration of other species.

CHAPTER XIII

The Empire of Fibers

I

"JUST look at yourself!" your mother no doubt used to say in tones that suggested a degree of displeasure at what her view of your person disclosed. By way of encouraging a bit of reader participation, and with the most dulcet of intentions, you are invited to look at yourself. And to look around you!

You are no doubt clad, or have the means at hand to become so. Your garments are fibers, hundreds of thousands of tiny fibers spun into yarn and woven into cloth. At your feet is a rug, and the rug is made up of other thousands of fibers. In the cloth on the table, in the draperies at the windows, in the materials of your bed are more fibers. If each fibrous component of the fabrics in your possession could be counted separately, you might very likely find yourself to be a multi-billionaire in fibers.

Next to food, fiber is the foremost economic necessity of man.

The vegetable, animal and mineral kingdoms all contribute to the abundance of fibers in nature. Until recently man has used fibers as he found them, with little alteration from their natural state. Now the synthetic manufacture of fiber has opened up a whole new range of raw materials and a whole new range of markets. The sheep and the silkworm and the cotton boll have new and formidable competitors. No woman can be sure today whether the stockings she will wear five years from now will be made from coal, air and water or silk, cotton or wool, or rayon or glass, steel or soybeans or milk.

The spirit of chemurgy reaches far into the fiber industries. Agriculture has candidate materials for thousands of the uses of fibers. Scores of continuing researches look to the increased utilization of farm-grown materials in the fiber markets; scores of other research programs threaten to diminish the dependence upon agricultural fibers. The established interests are immense, the competition is furious, and the stakes are vast. Zest for the contest is keen because all may be victors. The aggregate of human desires for fibers to warm and adorn their bodies and to add comfort to their surroundings is much greater than the supplies that have ever, so far, been available. Most of the two billion people on earth are not only ill-clad but ill-bedded and just ill because fibers have been too scarce and have cost too much.

II

Rayon is the foremost chemurgic product among fibers. The definition of chemurgy applies exactly. The soil provides the raw materials for rayon, and the product is a new use for those materials.

Wood pulp or cotton linters are the raw materials. The linters, as probably everyone knows, are not the longer fibers of the cotton boll but the seed fuzz which adheres after the ginning process is completed. Removed mechanically, the linters are 98 per cent usable cellulose. For its wood pulp the rayon industry prefers spruce or western hemlock. The pulp yields 92 per cent usable cellulose. Linters are therefore considered worth a trifle more although, being less stable in price, they can be said to have no constant preference.

Southern pine has since 1939 achieved a place among the trees suitable for rayon pulp. Other new processes make maple and birch acceptable.

From the first commercial beginning in France in 1884, rayon has steadily forged ahead among fabric materials. By 1943 production had risen to 663 million pounds in the United States and possibly 3.5 billion pounds in the world; roughly ten per cent of the U.S. fiber consumption had turned to rayon (cotton 80 per cent, wool 9, silk 1). The price of viscose rayon staple fiber in 1928 was sixty cents a pound. This dropped successively to fifty, forty, thirty-four and twenty-eight, until by the fall of 1937 twenty-five cents would buy a pound. The price has remained around that figure.

Research created rayon out of cottonseed fuzz and wood pulp and research improved the product until it filled a common human want for attractive finish and style. Research lowered the price until a poor person could buy rayon and research improved the quality until the rich were pleased to use it. A new product made a new market for raw materials, enriched living with a new fabric, and built a new industry with thousands of jobs.

III

As stated earlier, cotton was king. He was an arrogant king, reactionary and selfish. His virtues were so great, in his own opinion, that he needed no research. So it was very late when he realized that his crown was slipping, that part of his realm was indeed gone, and that he might have to hustle to keep alive.

Like many another monarch, when he found himself in danger he did the wrong thing first. Instead of sending for the scientists and engineers, he rushed to the politicians. They happily priced him out of the foreign markets to which he was accustomed and did their utmost to price him out of his domestic market. As has always been the way of courtiers, they flattered him into overestimating himself and underestimating his competitors.

If ever he learns to live in the modernized atmosphere of the twentieth century, forsaking his royal precedents and behaving as Mr. Cotton, an aggressive business citizen, rather than as a monarch, he may again prosper. For cotton is a plant with rugged virtues, genuine friends, and strong prospects.

The core of the cotton market is built around the superiority of its fiber for durable, low-priced textiles, notably those which need to withstand wear and wash and can emerge looking neat and feeling clean. The numbers of 500-pound bales consumed in various such uses each year are impressive: work shirts, trousers and overalls, 500,000 bales; men's business and dress shirts, 200,000 bales; underwear for men, 200,000 bales; towels, nearly 250,000 bales. For sheets and pillowcases cotton has all the market except for the very small number made with linen. Bags of countless kinds consume 500,000 bales. Automobile tires, requiring nearly 600,000 bales, have been the largest single outlet. That market has been challenged by rayon, which in 1937 first edged in when research discovered an adhesive that would bond the rubber to the fiber.

Curious to the outsider has been cotton's disposition to become deeply imbedded in trade practices which militated against the maximum use of cotton. Conspicuous among these has been the importation of jute from India to wrap up the cotton bale. Some twelve pounds of jute goes around the 500-pound bale. Bales would be neater and stronger, the tare would be less, and cotton patterns, as the wrapping strips are called, would have greater value than burlap for re-use. Probably as many as 150,000 bales would be needed to wrap up the crop. The appearance point is conspicuous in foreign ports where American cotton bales look ragged and uncouth in comparison to those arriving from competing countries.

With no discouragement from the British interests that control the jute business, the burlap wrapper is so tangled in the customs of the cotton trade as to be difficult to abandon. Before the war a subsidized deal was arranged by the government so that farmers would not be penalized when their bales were cotton-wrapped, and this was given a somewhat extensive trial. Whether the advantages then demonstrated will break through the barriers of custom, is not yet determined. Cotton bears a deep hatred for changes.

A give-away system was devised at the same time to "divert cotton and cotton products from their normal channels of trade." Extending the battleship deck idea of cotton duck as a durable flooring, cotton fabrics were tried in house construction for sidewalls, roofing, ceilings, flooring and insulation. Other fabrics were put out for stabilizing road cuts and fills, ditches and canal linings, for insulating and covering beehives in winter, for various horticultural uses, and for bags for peanuts.

Another trial, which may yet open up a large new demand for cotton, has been in the business of building roads. Each normal year about 45,000 miles of bituminous-surfaced roads have to be repaired in the United States and 20,000 additional miles are built. Some two million miles of roads are as yet unimproved, and most of these do not bear sufficient traffic to justify the first cost of concrete. A loosely-woven Osnaburg type of fabric, laid down between layers when the bituminous materials are applied, serves to reinforce and bind the surface; cracks, raveling at the edge, frost-heaves, and formation of holes in the surface are lessened. General adoption of cotton for this use awaits conclusive evidence that the cost of maintenance is reduced more than the fabric and its application costs.

The Southern Regional Research Laboratory includes a complete experimental cotton mill with more than $75,000 worth of textile machinery. From the series of fundamental and practical studies now under way a good many improvements on cotton utilization are confidently expected. This laboratory discovered the method of making sand bags rot-proof, which had extensive war uses and undoubtedly will increase the use of cotton in several types of bags.

"For the sole purpose of increasing the consumption of cotton plant products," according to its director of research, Dr. Simon Williams, the National Cotton Council is supported by units from all branches of the industry. This is the most comprehensive of all of King Cotton's belated ventures into science. The program in research ranges from fundamental studies in the physiology of the plant to uses of cotton in plastics and in trials of high-frequency electrostatic fields for killing insect pests in the cotton fields. Among the several energetic approaches being applied by the National Cotton Council is the maintenance of an experimental farm near Acapulco, in southern Mexico, so that in genetic studies two crops a year can be grown to expedite results.

IV

Why pick cotton? Few of the great annual agricultural tasks are half as laborious as cotton picking. While one hand drags a long, heavy sack, fingers reach into the bolls one by one to pluck out the small bouquets of white fiber. To gather enough to make a bale is a good half-week's work for one person working through long, monotonous days. Because the fiber does not ripen all at once, usually three trips must be made over the fields.

On the level plantations of the Mississippi Delta and in some other areas, the mechanical picker has been making headway. Airplane dusting of the fields with cyanamid dust to defoliate the plants has improved the operation. The chemical eliminates the admixture of leaves with the fiber and prevents the virtually irremovable stains caused by crushed green leaves. The mechanical pickers are large, expensive machines and they do not work well in small patches nor on other than level lands. If generally adopted in the level cotton areas they will put the southeastern growers at a new disadvantage.

The cotton plant produces two materials that rank high in the field of chemical raw stuffs. One is the oil in the seed. The far more important one is cellulose. Reasoning that the cellulose-consuming manufacturer was more interested in the cellulose than in where it came from, Dr. Frank K. Cameron, professor of chemistry at the University of North Carolina, decided that there was sound sense in the question, "Why pick cotton?"

Dr. Cameron's idea is to harvest the whole cotton plant and extract all the cellulose, rather than to waste all except the portion concentrated in the lint and linters. About 45 per cent of the weight of the dried whole cotton plant is cellulose.

After experiments that have proceeded slowly and with little financial support since 1929, Dr. Cameron, always conservative in his conclusions, has become fairly optimistic that commercial development will now be justified.

The plant is cut about four inches above the ground with a machine which mows and bales as it goes—in striking contrast to the labor requirement of the traditional cotton harvest; then the whole plant is ground so that the woody stems, the cusps and seeds are in small pieces with a large total surface exposed. A warm alkali solution removes, in a few hours, the coloring matter and some other substances; a fat solvent takes out the oil. The residue, washed with dilute aqueous sodium hydroxide, is easily bleached. The grinding costs no more than the barking and chipping of wood; the bleaching requires less material. About 5000 pounds of dried whole cotton is an average yield per acre.

With paper, rayon, artificial leather, plastic and other industries constantly demanding huge quantities of cellulose, Dr. Cameron believes that successful commercial operation of the process might well save the southeastern states from the serious consequences of the profound changes apparently befalling lint-cotton agriculture. In the southeast the farms are not adapted, by topography or habit, to utilize advantageously the mechanical picker, airplane dusting, and in many cases not even to use a tractor. Whole cotton production would eliminate the more laborious hand operations. Because it can be harvested before the boll weevil infestation period sets in, that menace to profits can be avoided.

Science and engineering join, under Cameron's plan, to produce more profitably a cheaper raw material. The approach is genuinely chemurgic.

V

The average American in 1909 consumed 1880 pounds of farm products. Thirty years later he consumed 1882 pounds. That includes the products eaten, worn and otherwise used up.

His consumption of fibers for wearing apparel in 1909 was estimated at 30 pounds. The estimate for 1939 was 34.3, and for 1940 it was 36.7 pounds.

Either the average person was eating no more food or he was eating less, if Department of Agriculture estimates are correct; unless, as is unlikely, farm product consumption changed notably in other forms than food and apparel fiber.

These careful estimates, at any rate, confirm the chemurgic thesis that while people do not increase their total consumption of food, they do expand their consumption of almost everything else. The consumption of apparel fibers at an earlier date, 1892-94, was only 22.4 pounds. The increase during fifty years had been more than 60 per cent.

While much is said about the fury of competition among fibers, as between cotton and rayon or between nylon and silk, this competition is actually no more than one chapter in the book. The truth about fibers is that whenever a better or different fiber appears on the market, a fiber that fills a new purpose, meets a new want, does something better than predecessor materials, buyers will lay down their dollars for it if the price is fair. We have just noted that the market for fibers for wearing apparel has risen more than 60 per cent within fifty years. During that period whole new fields of fiber uses have developed, such as automobile upholstering and automobile tire manufacturing. Undoubtedly more needs will arise in the future.

When one takes into account the fact that relatively few people have all the clothing they would like to own, the field for expansion of fiber consumption appears tremendous. In all seriousness, how many women own as many garments as they think necessary to their best appearance? How many men, for that matter, own as many suits, shirts, shorts and other garments as they could well use? How many houses are underequipped with linens, draperies, towels, and the other textile adjuncts to comfort and appearance? In the lower income brackets are millions of houses which have no rugs on the floors, and much less are they well provided with window draperies or adequate bedding and table textiles.

The potential for expansion in fiber consumption during the next fifty years is surely no less than it was in the half century just past. It may well be much greater, for the broad base of demand is wider. Competition between fibers may well be intense for markets not now existing, rather than for old markets where each has demonstrated superior qualities for specific purposes. At any rate, the room for newer, better, cheaper fibers, is an immense, yet-to-be-filled space. The public will not ask whether these new fibers are synthetic or natural if only they are satisfactory.

VI

Suppose a remarkable new natural fiber came into the markets with an abundance of amazing merits. What would be the prospect for demand if this new fiber lived up to all or nearly all of the claims made for its qualities, most of which appear to be fairly well authenticated?

1. In tensile strength, eight times that of cotton and silk, four times that of flax, and three times that of hemp.

2. Equally elastic with cotton, considerably more elastic than flax or hemp, though less elastic than silk.

3. Torsion strength, substantially better than flax or hemp, though much below cotton and silk.

4. When wet, 30 to 60 per cent stronger than when dry.

5. Slightly more absorbent than cotton (will hold water up to 28.5 per cent of its dry weight, compared to cotton's 26 per cent).

6. Absorbs water more quickly than flax, dries more quickly, and is affected very little by the moisture.

7. Gives off no lint, as cotton does.

8. Takes commercial dyes well and holds color better than other fibers.

9. Can be spun and woven, either alone or blended with other fibers, on all standard machinery such as is now used for cotton, rayon, silk or wool.

10. When woven with wool, prevents shrinkage.

11. A superior summer fiber because it absorbs perspiration easily, dries quickly, washes well and is light and cool.

12. Length of staple averages 6 to 8 inches, running from 5 to 22 inches, being the longest of any commercial natural

fiber. Cotton fibers run from seven-eighths to one and one-fourth (except long staple), flax and hemp about one and one-fourth, wool about five inches.

13. Suitable for tough, high-grade papers, such as currency and bond papers, where strength, elasticity and opacity are esteemed.

14. Washes with extreme ease and the most difficult stains can be removed.

15. Fabrics blended with other common fibers possess new and attractive qualities, and hold their shape well.

Marvelous, isn't it? In fact, "colossal, in a small way," as Sam Goldwyn is alleged to have conceded.

Does it really exist? Yes, and it has been known and used by men for perhaps three thousand years. Moreover, it grows rather easily in several southern areas of the United States. The fiber yield under proper cultivation is reported at 500 to 800 pounds per acre, equal to good cotton production, and the by-product potential is considerable.

The fiber is ramie, pronounced, by the way, with short vowels. And few fibers have racked more good brains. Eli Whitney, according to history, spent only a few days making the first cotton gin. Hundreds of men have spent years and fortunes trying to figure out a way to extract the fibers cheaply from the ramie plant and to condition them satisfactorily for use. Successful decortication and degumming on a commercial scale has stumped man after man. Long years ago inventors struggled with the fiber. The 1905 edition of Encyclopedia Britannica relates the disappointing results from machines attempted up to that date.

The center of the ramie stalk is pithy. A woody layer surrounds the pith. The fibers lie in the inner bark surrounding this woody layer. A thin outer bark, rich in tannic acid, covers the stalk.

In China, from where some ramie has been exported as

"China grass," one man can remove the fiber from the stalk at the rate of from three to six pounds a day. The status there is about the same as that of cotton here before Whitney whittled out the cotton gin.

The ramie plant eclipses its fibrous competitors in still other ways. Planted most easily from root cuttings, within six or eight weeks the stalks have shot up to cutting size. Three or more crops a year may be harvested. No replanting is necessary until after four or five years. By that time the vigorous perennial roots so fill the soil that it becomes root-bound, so that a new location is necessary. No insect or disease pests appear to damage the plant. No more fertilizer is required than for cotton. It flourishes on relatively low-priced, poor soils. Unless frost penetrates the ground three or four inches the plant does not winterkill.

"Once the virus of ramie gets into your blood it stays with you until, like the Pharaohs, you are ready for your mummy wrappings." That statement was made by Herman W. Hawker, president of the 19,000-acre Leone Plantation in Leon County, Texas, east of Waco and northwest of Houston. Hawker was inoculated with the "virus of ramie" by a Philadelphia textile manufacturer who formerly owned the plantation and who, asserting that ramie was "queen of all fibers," urged that Hawker take up its study. That was about 1938. Hawker has since then been growing substantial experimental acreages each year, investigating work done with all phases of the product, undertaking its genetic improvement, and attempting to solve the decortication problem. He is confident that in the Gulf states ramie production will become an important supplement to the cotton economy.

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VII

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Nevertheless only flax will make fine linens, and flax still is preferred for certain kinds of thread and cordage, sailcloth and some other uses. Just before the war, in 1939, the imports of flax linen fiber were 4126 tons. The domestic production that year was 220 tons.

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These four constituted the sole insurance that the United States would have a flax industry in the event of war. When war came we were in the customary state of unpreparedness. Imports were shut off. The price of flax fiber doubled quickly from 28½ cents to 58 cents per pound. The better price induced the launching of four unsubsidized plants, two built by farm cooperatives and two by individual interests. Still, facilities and production were insufficient to meet the demands of the textile branch of the War Production Board. Flax was urgently needed for shoe sewing thread, webbing and fire hose. Six additional plants had to be constructed; two of them were built and leased by the Defense Plants Corporation. Fiber production moved rapidly up from the pre-war 220 tons to 3400 tons per year, a figure which approached the former imports.

The Oregon flax business is neither strong nor sound. In addition to a portion of the processing plants being built by public funds, growers received subsidies from 1936 to 1941 ranging from $2.08 to $7.50 for each ton of straw delivered.

The peace-time import record, plus disappearance of the small domestic crop, points to a stable American demand for upwards of four thousand tons of flax fiber each year. Relatively little research has been expended on reducing production costs. While steps have been taken that are great advances over the hand methods still pursued in most of Europe, better mechanical pullers, combine-harvesters and scutching machines must be developed. Engineering research, even since 1938, has definitely lowered costs and improved quality.

Subsidies carry with them a quality of uncertainty. They are subject to change, or withdrawal. Research gains are permanent until superseded by better research gains. With sufficient research the present Oregon rural flax industry, worth three or four million dollars a year, may be able to continue. It may be able to expand, for the virtues of flax fiber are too well appreciated to fail to hold a substantial market in a nation which steadily increases its total consumption.

An America provided with a thousand small industries will always be better prepared to live, to prosper or to fight, than will an America which tolerates gaps, however small, in its economic armor.

VIII

Ever since colonial times some Americans have grown hemp. But never has it become a major crop, except in limited and local areas.

The acreage tapered off until during the nineteen-thirties. Wisconsin and Kentucky produced about all that was left, hardly two thousand acres in all, with the greater portion in Wisconsin. A concern in Boston, evidently determined that American-grown hemp should not disappear, was the one remaining buyer. Six small mills processed the entire output.

That was the situation on December 19, 1942, a year after Pearl Harbor, when the War Production Board issued *Program Determination No. 70*. The previous spring the seed supply was frozen and 36,000 acres were ordered to be planted to increase the seed. Program Determination No. 70 requested the Department of Agriculture to get 300,000 acres of hemp produced for fiber and 50,000 acres for seed the next year; that, and to build 71 new decorticating mills. Despite herculean effort and additional seed hurriedly imported from Chile, the planting was 168,000 acres, of which about 132,000 acres were harvested. The construction program was cut to 42 mills. These were built at an average cost of $290,000 each, about $60,000 less than the estimates. Eleven each are in Minnesota, Iowa and Illinois, six in Wisconsin, two in Indiana, one in Kentucky. Special harvesting machines to the number of 2435, were hurriedly made by two implement companies.

Thus for war purposes hemp acreage and processing facilities were multiplied, respectively and roughly, by seventy and by seven. The war is finished. What future has American hemp?

The truth is that science and engineering have not been applied to hemp. Despite its long adaptation to American farming, its excellent yields, and its merits as a fiber, hemp has never enjoyed the advantages of modernization. The handling of the crop is still not far from primitive. Parts are yet in the hand-labor stage. Retting is inefficiently performed. Spinners complain that portions of the hurds and undesirable materials adhere to the fibers that reach them. Grading has been equally primitive and unstandardized.

For cordage other fibers from other lands have come to be preferred. During an eight-year period 57,700 long tons (yearly average) of abaca or manila fiber have been brought from the Philippines. Hennequen from Mexico and Cuba, sisal from the East Indies, British East Africa, Cuba and Haiti, have averaged 160,500 long tons yearly. From India have come 63,000 tons of jute and jute butts a year. Contrasted with this total of 280,000 long tons of other cordage fibers, the yearly imports of true hemp averaged about 656 tons; hardly enough, a cynic might remark, to hang all the rascals in the country. Hemp, obviously, was not wanted very badly.

A soft-fiber spinner of Boston, Mr. E. S. Boote, nevertheless declared to an Iowa conference of men interested in hemp that "It is our firm belief that American hemp is capable of great utility in the textile world, a good deal of which has already been realized in manufacturing results. . . . If there is failure, it will be because properly-retted, milled and graded line fiber has not been made available to the spinners. If No. 1 quality fiber can be prepared by the fiber producers, a substantial and continuous demand will appear both from the United States and from abroad."

Cordage apparently is not the most promising outlet for American-grown hemp. Another student of hemp, George E. Farrell of the Bureau of Agricultural Economics, told the same Iowa gathering that "it can command a wide market as twine, rug warp and filler, clothes line, furniture twine and webbing, hat braid, canvas and clothing." Durable and satisfactory towels are among the several fabric products which have been exhibited by hemp experimenters. Fire hose, bagging, shoe cloth, linoleum backing and bed linen are other textile uses which hemp advocates believe may be in their future.

India's jute, produced by labor receiving thirty-five cents for an eighty-hour week, was cited by Senator Gillette, during hearings on fibers, as a major competitor of American hemp.

IX

The fact that a plant yields a fiber affords no assurance that it will yield a profit. Production, harvest, processing, spinning and weaving all cost labor and money. None of these essential operations will be performed until evidence appears that consumers, the final arbiters of even a managed economy, desire the product sufficiently to pay the costs.

Milkweed stalks yield a long, tough bast fiber. Should other products of the milkweed some time command a sufficient price to encourage cultivation of this interesting plant, and should it be possible to harvest the plant so as to include the fiber without loss of the other desired values, milkweed fiber might become a commercial item. In the present state of affairs and the present state of knowledge about the weed, no one would attempt to harvest the wild crop for fiber if he were inspired only by the low motive of profits.

The castor bean, now under limited cultivation and easily grown, has not yet induced anyone to undertake commercialization of the fiber, although it is long and strong, reaching from root to tip.

The nolina, locally known in the Southwest desert as bear grass or sacahuiste, is an example of a fiber that reaches over the margin into commercial practicability. Used for heavy brushes and brooms, nolina is cut with an ax at the root, is allowed to dry in the sun, is trimmed to 18- or 24-inch lengths, and baled. Not preferred by livestock, its removal is welcomed by ranchmen who consider their pastures improved by its destruction. The price during the war was as much as $40 a ton at the baler.

The glauca yucca of the same area, also known as bear grass and sometimes as soapweed, found a war market at $40 to $60 a ton for baled leaves. An eastern mill bought it for processing into a special paper said to be required by the Navy. The fiber is about as strong as sisal or hemp. During the 1914-18 war one company produced eighty million pounds of glauca yucca as a substitute for jute in the making of burlap and bagging.

Four or five species of yuccas which grow wild in the Rio Grande country and elsewhere in the Southwest possess strong fibers. Those of the Spanish bayonet type, with rigid leaves, equal manila hemp (abaca) in strength. A pull of 2940 pounds was necessary to break a three-fourths inch rope of yucca elata.

The scientific test of fiber strength projects the length of the fiber itself to a weight sufficient to break the strand. Yucca baccata revealed a breaking strength of 60 kilometers—

that is to say, a single strand would need to be 37 miles long before it would break of its own weight.

The desert fibers exist in abundance far beyond any demand that has so far appeared. They reproduce and grow again readily, the rate apparently depending mostly upon the amount of rainfall. Should new facts be discovered that would create a demand for their particular qualities, the desert fibers might well become of genuine economic importance. As matters now rest, their presence is a stand-by, should a future national emergency call for their use.

Such tropical fiber plants as Sansevieria or bow-string hemp have undergone limited experimentation in Florida without becoming established as yet. Okra and buttonweed are among many commoner plants with fiber possibilities that have not yet been found economically interesting. Jute, one of the most commonly-used fibers in the United States, is grown almost entirely in Bengal and is processed principally in Edinburgh. Americans merely pay for it and use it. Whether any home-grown fiber will serve as cheaply for the burlap, bagging and cordage now made from jute is an open question which no one seems ever to have tried very hard to answer. The post office department has in recent years found a type of cotton string which, like jute, breaks easily and does not injure the postal workers' hands. But most of American cotton bales are still wrapped in jute patterns.

CHAPTER XIV

Wealth from the Woods

I

MAN has long marveled at the wonderful usefulness and beauty of wood. He has been grateful for the strength of the oak, the abundance of pine, the softness of the basswood, and the rich beauty of mahogany and ebony. With wood he has built and warmed his house, devised his tools and weapons, bridged his streams and has found a species with admirable qualities for each of a thousand uses. But he has not marveled nearly enough!

The ax and saw, those mighty tools of the pioneer, transformed millions of trees into lumber and fuel. The drawknife, the chisel, the plane and the lathe shaped pieces of wood into a billion articles of utility and beauty. Yet to the modern toilers with wood they are primitive tools, crudely suitable for simple purposes.

One of the most abundant and widespread of raw materials, wood has a profoundly logical appeal to the modern chemist. To him a tree is more than an object to be measured in board feet. A log to him is a package of cellulose, a reservoir of lignin, a source of turpentine. From his processes the log may emerge as a newspaper, a pair of rayon panties, a drum of alcohol, a box of sugar, a shining plastic, a bottle of oil or a vial of camphor. Or it may still be wood, but wood such as man never dreamed about nor saw until now.

II

A story of wood, phenomenal, astonishing, important and, in a way, so simple that it must eventually rank high among the useful scientific advances of war times, may well be prefaced by following the chemist through a few preliminary steps before he reaches for a piece of lumber.

Ammonia, one of the great commercial syntheses, is a product derived from coal and air and water. So, also, is carbon dioxide. And so is methanol. From methanol formaldehyde is derived. The reaction of ammonia and carbon dioxide creates urea. When formaldehyde is condensed with urea, one product is called dimethylolurea. If some urea is added to some dimethylolurea, one syllable, for some reason, disappears. The chemical then is called methylolurea.

Methylolurea is a white solid or powder. It will dissolve in water. Methylolurea is cheap because urea and all the other chemicals necessary to its preparation are cheap and abundant, which fact is the result of large demand, highly perfected processes, and abundant original raw materials.

Water, too, is cheap.

Scientists at the Forest Products Laboratory, a splendid government research institution at Madison, Wisconsin, were the first to associate urea and wood. They hit upon the idea of soaking a board in a solution of water and urea.

A chemist always wonders what will happen if he applies heat and pressure, since these forces frequently initiate reactions that do not otherwise occur. So they warmed up the board that soaked in urea and water. They tried different strengths of solution. They found that when the solution was strong with urea, forty per cent or more, and the wood was heated to 200 degrees, near the boiling point for plain water, the board became virtually limp. It could be twisted or bent as no board ever could before. A small half-inch board could be bent into a half circle with a radius of only three-fourths of an inch. A small plank an inch and a half thick would bend on a five-inch radius.

That was only remarkable. When the bent board cooled off it stayed bent—kept the exact shape into which it had been forced when hot! That was amazing; and important, and valuable.

If they heated it again it could be bent back straight, or into some other shape. Or, if they added formaldehyde to the solution, they could heat the bent shape again and it would *not* change back from its new shape.

They had, in effect, created with a piece of wood a thermosetting plastic. They had a treated wood that would set in a new shape permanently and would not become plastic again. The wood also became stiffer, harder, and more resistant to water.

The Forest Products Laboratory realized that they had achieved with wood an effect analagous to the alloys of metals. Just as iron and carbon make steel, wood and urea made something new that was not merely wood. So they called it uralloy and took out public service patents on the procedures.

The Du Pont research organization, interested in outlets for urea as well as in making wood more useful, found a fascinating range of possibilities in the urea-wood combination.

Their experiments led to the use of dimethylolurea and urea as chemicals to effect the most desirable transmutation of wood. Transmutation is not too strong a word for, as a Du Pont writer has said, the changes effected turn wood into substances "as different from the original as steel is from iron. . . . Poplar becomes harder than hard maple, which in turn can be made harder than ebony."

Not only does the process make wood harder, stiffer, stronger and more durable, but it reduces warping, swelling or shrinking, and retards the grain from rising in the presence of moisture. Greater precision in cutting and shaping is made possible. The wood becomes more resistant to flame, rot, pests, and chemicals.

Treatment penetrates throughout the wood. A scratch may be smoothed out because the appearance underneath the surface is exactly the same. Woods with an attractive appearance, but which in their natural state are too soft, perishable or unworkable for furniture or other important uses, may now be utilized in fields hitherto closed to them. If the natural color is not good enough, dyes can be mixed with the methylolurea. Then "light colored pine can take on the hues of cherry, the glamour of rosewood, or the depth of mahogany, or it may be colored in brilliant reds, greens or purples."

The actual process of transmutation, if described fully in chemical terms, would no doubt seem highly complicated. In practice the application is simple. Dried sap wood is impregnated with a water solution of dimethylolurea and urea. These chemicals in the treated wood resinify during the subsequent air or kiln drying. If the kiln-dried wood is heated to 240° F. or higher, the resins will melt and flow under pressure. Then the shape of the wood may be changed. If greater density is desired, the wood can be compressed. Polished or embossed surfaces can be obtained by pressure.

"Now wood can be remade—engineered to specifications of service and appearance," according to an enthusiast for the process. "The shackles of unalterable properties and of limitations to certain species can now be cast aside.

"Manufactured articles such as veneers, furniture, textile and other machinery parts, sports goods, musical instruments, tool, knife and kitchen utensil handles, millwork, screen, window and door sashing, rollers, shoe lasts, tanks, sanitary ware, laundry and chemical equipment, agricultural implement parts and many other items would be improved by manufacture from this treated wood.

"Large quantities of woods are available but not used because they are too soft or weak, or crush and dent too easily, are not durable, or present turning, working or finishing difficulties. The sap portion of such low-cost species can now be improved.

"Such woods as soft maple, tupelo gum, yellow poplar, a number of pines and other woods can be treated to improve their usefulness. They could be used to release hard maple, oak, walnut and other more desirable but less available and costlier woods. In turn, these woods, too, can be improved.

"Tidewater cypress with pleasing grain, California redwood with its satin texture and warm red color, and our almost white cottonwood, matching the best bleached woods, are but a few of the examples of the many woods that may now compete on even terms with other species.

"Advantage can now be taken of the natural beauty of these species in spite of the inherent defects that previously limited their uses. Hardness, finish, strength, density and durability can now be contributed by the treatment and one may in the future enjoy new furniture—even floors—of beautiful woods that never before could be used for flooring or furniture. They will be difficult to mar and can be readily restored to their original beauty if damaged."

III

Fire broke out in a Madison, Wisconsin, lumber yard one morning in June, 1944. Few merrier playgrounds for the fire demons are to be found than a well-stocked lumber yard. Here, besides large quantities of well-seasoned dry lumber, were many tons of coal which caught fire. Three companies of firemen did their utmost.

By the time the blaze was extinguished three hours later, one building 120 x 80 feet had been destroyed. The coal shed, stores of millwork, three trucks, and a considerable part of the lumber stock had been turned to ashes and charred debris.

Fifty thousand feet of other lumber, stored in the midst of the consumed material, remained unburned. The ends and exposed sides of the piles were charred a little. The flames had not taken hold.

That was flame-proofed lumber. Treated with phosphatic chemicals, it would char a little but would neither flame nor glow, despite the terrific heat which had surrounded the piles. So far there is no such thing as fireproof wood. Flameproofing, fire retardant treatment, however, is pretty good—good enough that ordnance plants, airship hangars, synthetic rubber factories and railroad buildings have consumed huge quantities of it in recent years, and its use grows. The process has made wood a better material than it was when nature created it.

Another important chemical improvement of wood has to do with its preservation. Creosotes and various salts have been used for a long time. Improved results are being obtained with chlorinated phenols. Colorless and not objectionable to handle, these materials are carried in a cheap petroleum base such as kerosene. Water repellents may be included in the treating mixture. Electric poles and cross arms, fence posts and other exposed articles have been improved with this new chemical preservative.

IV

A forest of trees that reaches skyward with clean trunks two or three feet in diameter is wealth in an obvious form. Anyone with a sawmill can make them into lumber, and for lumber a market always exists.

William H. Mason, once an associate of Thomas A. Edison, saw no mighty tree trunks in the forests around Laurel, Mis-

"China grass," one man can remove the fiber from the stalk at the rate of from three to six pounds a day. The status there is about the same as that of cotton here before Whitney whittled out the cotton gin.

The ramie plant eclipses its fibrous competitors in still other ways. Planted most easily from root cuttings, within six or eight weeks the stalks have shot up to cutting size. Three or more crops a year may be harvested. No replanting is necessary until after four or five years. By that time the vigorous perennial roots so fill the soil that it becomes root-bound, so that a new location is necessary. No insect or disease pests appear to damage the plant. No more fertilizer is required than for cotton. It flourishes on relatively low-priced, poor soils. Unless frost penetrates the ground three or four inches the plant does not winterkill.

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These four constituted the sole insurance that the United States would have a flax industry in the event of war. When war came we were in the customary state of unpreparedness. Imports were shut off. The price of flax fiber doubled quickly from 28½ cents to 58 cents per pound. The better price induced the launching of four unsubsidized plants, two built by farm cooperatives and two by individual interests. Still, facilities and production were insufficient to meet the demands of the textile branch of the War Production Board. Flax was urgently needed for shoe sewing thread, webbing and fire hose. Six additional plants had to be constructed; two of them were built and leased by the Defense Plants Corporation. Fiber production moved rapidly up from the pre-war 220 tons to 3400 tons per year, a figure which approached the former imports.

The Oregon flax business is neither strong nor sound. In addition to a portion of the processing plants being built by public funds, growers received subsidies from 1936 to 1941 ranging from $2.08 to $7.50 for each ton of straw delivered.

The peace-time import record, plus disappearance of the small domestic crop, points to a stable American demand for upwards of four thousand tons of flax fiber each year. Relatively little research has been expended on reducing production costs. While steps have been taken that are great advances over the hand methods still pursued in most of Europe, better mechanical pullers, combine-harvesters and scutching machines must be developed. Engineering research, even since 1938, has definitely lowered costs and improved quality.

Subsidies carry with them a quality of uncertainty. They are subject to change, or withdrawal. Research gains are permanent until superseded by better research gains. With sufficient research the present Oregon rural flax industry, worth three or four million dollars a year, may be able to continue. It may be able to expand, for the virtues of flax fiber are too well appreciated to fail to hold a substantial market in a nation which steadily increases its total consumption.

An America provided with a thousand small industries will always be better prepared to live, to prosper or to fight, than will an America which tolerates gaps, however small, in its economic armor.

VIII

Ever since colonial times some Americans have grown hemp. But never has it become a major crop, except in limited and local areas.

The acreage tapered off until during the nineteen-thirties. Wisconsin and Kentucky produced about all that was left, hardly two thousand acres in all, with the greater portion in Wisconsin. A concern in Boston, evidently determined that American-grown hemp should not disappear, was the one remaining buyer. Six small mills processed the entire output.

That was the situation on December 19, 1942, a year after Pearl Harbor, when the War Production Board issued *Program Determination* No. 70. The previous spring the seed supply was frozen and 36,000 acres were ordered to be planted to increase the seed. Program Determination No. 70 requested the Department of Agriculture to get 300,000 acres of hemp produced for fiber and 50,000 acres for seed the next year; that, and to build 71 new decorticating mills. Despite herculean effort and additional seed hurriedly imported from Chile, the planting was 168,000 acres, of which about 132,000 acres were harvested. The construction program was cut to 42 mills. These were built at an average cost of $290,000 each, about $60,000 less than the estimates. Eleven each are in Minnesota, Iowa and Illinois, six in Wisconsin, two in Indiana, one in Kentucky. Special harvesting machines to the number of 2435, were hurriedly made by two implement companies.

Thus for war purposes hemp acreage and processing facilities were multiplied, respectively and roughly, by seventy and by seven. The war is finished. What future has American hemp?

The truth is that science and engineering have not been applied to hemp. Despite its long adaptation to American farming, its excellent yields, and its merits as a fiber, hemp has never enjoyed the advantages of modernization. The handling of the crop is still not far from primitive. Parts are yet in the hand-labor stage. Retting is inefficiently performed. Spinners complain that portions of the hurds and undesirable materials adhere to the fibers that reach them. Grading has been equally primitive and unstandardized.

For cordage other fibers from other lands have come to be preferred. During an eight-year period 57,700 long tons (yearly average) of abaca or manila fiber have been brought from the Philippines. Hennequen from Mexico and Cuba, sisal from the East Indies, British East Africa, Cuba and Haiti, have averaged 160,500 long tons yearly. From India have come 63,000 tons of jute and jute butts a year. Contrasted with this total of 280,000 long tons of other cordage fibers, the yearly imports of true hemp averaged about 656 tons; hardly enough, a cynic might remark, to hang all the rascals in the country. Hemp, obviously, was not wanted very badly.

A soft-fiber spinner of Boston, Mr. E. S. Boote, nevertheless declared to an Iowa conference of men interested in hemp that "It is our firm belief that American hemp is capable of great utility in the textile world, a good deal of which has already been realized in manufacturing results. . . . If there is failure, it will be because properly-retted, milled and graded line fiber has not been made available to the spinners. If No. 1 quality fiber can be prepared by the fiber producers, a substantial and continuous demand will appear both from the United States and from abroad."

Cordage apparently is not the most promising outlet for American-grown hemp. Another student of hemp, George E. Farrell of the Bureau of Agricultural Economics, told the same Iowa gathering that "it can command a wide market as twine, rug warp and filler, clothes line, furniture twine and webbing, hat braid, canvas and clothing." Durable and satisfactory towels are among the several fabric products which have been exhibited by hemp experimenters. Fire hose, bagging, shoe cloth, linoleum backing and bed linen are other textile uses which hemp advocates believe may be in their future.

India's jute, produced by labor receiving thirty-five cents for an eighty-hour week, was cited by Senator Gillette, during hearings on fibers, as a major competitor of American hemp.

IX

The fact that a plant yields a fiber affords no assurance that it will yield a profit. Production, harvest, processing, spinning and weaving all cost labor and money. None of these essential operations will be performed until evidence appears that consumers, the final arbiters of even a managed economy, desire the product sufficiently to pay the costs.

Milkweed stalks yield a long, tough bast fiber. Should other products of the milkweed some time command a sufficient price to encourage cultivation of this interesting plant, and should it be possible to harvest the plant so as to include the fiber without loss of the other desired values, milkweed fiber might become a commercial item. In the present state of affairs and the present state of knowledge about the weed, no one would attempt to harvest the wild crop for fiber if he were inspired only by the low motive of profits.

The castor bean, now under limited cultivation and easily grown, has not yet induced anyone to undertake commercialization of the fiber, although it is long and strong, reaching from root to tip.

The nolina, locally known in the Southwest desert as bear grass or sacahuiste, is an example of a fiber that reaches over the margin into commercial practicability. Used for heavy brushes and brooms, nolina is cut with an ax at the root, is allowed to dry in the sun, is trimmed to 18- or 24-inch lengths, and baled. Not preferred by livestock, its removal is welcomed by ranchmen who consider their pastures improved by its destruction. The price during the war was as much as $40 a ton at the baler.

The glauca yucca of the same area, also known as bear grass and sometimes as soapweed, found a war market at $40 to $60 a ton for baled leaves. An eastern mill bought it for processing into a special paper said to be required by the Navy. The fiber is about as strong as sisal or hemp. During the 1914-18 war one company produced eighty million pounds of glauca yucca as a substitute for jute in the making of burlap and bagging.

Four or five species of yuccas which grow wild in the Rio Grande country and elsewhere in the Southwest possess strong fibers. Those of the Spanish bayonet type, with rigid leaves, equal manila hemp (abaca) in strength. A pull of 2940 pounds was necessary to break a three-fourths inch rope of yucca elata.

The scientific test of fiber strength projects the length of the fiber itself to a weight sufficient to break the strand. Yucca baccata revealed a breaking strength of 60 kilometers—

that is to say, a single strand would need to be 37 miles long before it would break of its own weight.

The desert fibers exist in abundance far beyond any demand that has so far appeared. They reproduce and grow again readily, the rate apparently depending mostly upon the amount of rainfall. Should new facts be discovered that would create a demand for their particular qualities, the desert fibers might well become of genuine economic importance. As matters now rest, their presence is a stand-by, should a future national emergency call for their use.

Such tropical fiber plants as Sansevieria or bow-string hemp have undergone limited experimentation in Florida without becoming established as yet. Okra and buttonweed are among many commoner plants with fiber possibilities that have not yet been found economically interesting. Jute, one of the most commonly-used fibers in the United States, is grown almost entirely in Bengal and is processed principally in Edinburgh. Americans merely pay for it and use it. Whether any home-grown fiber will serve as cheaply for the burlap, bagging and cordage now made from jute is an open question which no one seems ever to have tried very hard to answer. The post office department has in recent years found a type of cotton string which, like jute, breaks easily and does not injure the postal workers' hands. But most of American cotton bales are still wrapped in jute patterns.

CHAPTER XIV

Wealth from the Woods

I

MAN has long marveled at the wonderful usefulness and beauty of wood. He has been grateful for the strength of the oak, the abundance of pine, the softness of the basswood, and the rich beauty of mahogany and ebony. With wood he has built and warmed his house, devised his tools and weapons, bridged his streams and has found a species with admirable qualities for each of a thousand uses. But he has not marveled nearly enough!

The ax and saw, those mighty tools of the pioneer, transformed millions of trees into lumber and fuel. The drawknife, the chisel, the plane and the lathe shaped pieces of wood into a billion articles of utility and beauty. Yet to the modern toilers with wood they are primitive tools, crudely suitable for simple purposes.

One of the most abundant and widespread of raw materials, wood has a profoundly logical appeal to the modern chemist. To him a tree is more than an object to be measured in board feet. A log to him is a package of cellulose, a reservoir of lignin, a source of turpentine. From his processes the log may emerge as a newspaper, a pair of rayon panties, a drum of alcohol, a box of sugar, a shining plastic, a bottle of oil or a vial of camphor. Or it may still be wood, but wood such as man never dreamed about nor saw until now.

II

A story of wood, phenomenal, astonishing, important and, in a way, so simple that it must eventually rank high among the useful scientific advances of war times, may well be prefaced by following the chemist through a few preliminary steps before he reaches for a piece of lumber.

Ammonia, one of the great commercial syntheses, is a product derived from coal and air and water. So, also, is carbon dioxide. And so is methanol. From methanol formaldehyde is derived. The reaction of ammonia and carbon dioxide creates urea. When formaldehyde is condensed with urea, one product is called dimethylolurea. If some urea is added to some dimethylolurea, one syllable, for some reason, disappears. The chemical then is called methylolurea.

Methylolurea is a white solid or powder. It will dissolve in water. Methylolurea is cheap because urea and all the other chemicals necessary to its preparation are cheap and abundant, which fact is the result of large demand, highly perfected processes, and abundant original raw materials.

Water, too, is cheap.

Scientists at the Forest Products Laboratory, a splendid government research institution at Madison, Wisconsin, were the first to associate urea and wood. They hit upon the idea of soaking a board in a solution of water and urea.

A chemist always wonders what will happen if he applies heat and pressure, since these forces frequently initiate reactions that do not otherwise occur. So they warmed up the board that soaked in urea and water. They tried different strengths of solution. They found that when the solution was strong with urea, forty per cent or more, and the wood was heated to 200 degrees, near the boiling point for plain water, the board became virtually limp. It could be twisted or bent as no board ever could before. A small half-inch board could be bent into a half circle with a radius of only three-fourths of an inch. A small plank an inch and a half thick would bend on a five-inch radius.

That was only remarkable. When the bent board cooled off it stayed bent—kept the exact shape into which it had been forced when hot! That was amazing; and important, and valuable.

If they heated it again it could be bent back straight, or into some other shape. Or, if they added formaldehyde to the solution, they could heat the bent shape again and it would *not* change back from its new shape.

They had, in effect, created with a piece of wood a thermosetting plastic. They had a treated wood that would set in a new shape permanently and would not become plastic again. The wood also became stiffer, harder, and more resistant to water.

The Forest Products Laboratory realized that they had achieved with wood an effect analagous to the alloys of metals. Just as iron and carbon make steel, wood and urea made something new that was not merely wood. So they called it uralloy and took out public service patents on the procedures.

The Du Pont research organization, interested in outlets for urea as well as in making wood more useful, found a fascinating range of possibilities in the urea-wood combination.

Their experiments led to the use of dimethylolurea and urea as chemicals to effect the most desirable transmutation of wood. Transmutation is not too strong a word for, as a Du Pont writer has said, the changes effected turn wood into substances "as different from the original as steel is from iron. . . . Poplar becomes harder than hard maple, which in turn can be made harder than ebony."

Not only does the process make wood harder, stiffer, stronger and more durable, but it reduces warping, swelling or shrinking, and retards the grain from rising in the presence of moisture. Greater precision in cutting and shaping is made possible. The wood becomes more resistant to flame, rot, pests, and chemicals.

Treatment penetrates throughout the wood. A scratch may be smoothed out because the appearance underneath the surface is exactly the same. Woods with an attractive appearance, but which in their natural state are too soft, perishable or unworkable for furniture or other important uses, may now be utilized in fields hitherto closed to them. If the natural color is not good enough, dyes can be mixed with the methylolurea. Then "light colored pine can take on the hues of cherry, the glamour of rosewood, or the depth of mahogany, or it may be colored in brilliant reds, greens or purples."

The actual process of transmutation, if described fully in chemical terms, would no doubt seem highly complicated. In practice the application is simple. Dried sap wood is impregnated with a water solution of dimethylolurea and urea. These chemicals in the treated wood resinify during the subsequent air or kiln drying. If the kiln-dried wood is heated to 240° F. or higher, the resins will melt and flow under pressure. Then the shape of the wood may be changed. If greater density is desired, the wood can be compressed. Polished or embossed surfaces can be obtained by pressure.

"Now wood can be remade—engineered to specifications of service and appearance," according to an enthusiast for the process. "The shackles of unalterable properties and of limitations to certain species can now be cast aside.

"Manufactured articles such as veneers, furniture, textile and other machinery parts, sports goods, musical instruments, tool, knife and kitchen utensil handles, millwork, screen, window and door sashing, rollers, shoe lasts, tanks, sanitary ware, laundry and chemical equipment, agricultural implement parts and many other items would be improved by manufacture from this treated wood.

"Large quantities of woods are available but not used because they are too soft or weak, or crush and dent too easily, are not durable, or present turning, working or finishing difficulties. The sap portion of such low-cost species can now be improved.

"Such woods as soft maple, tupelo gum, yellow poplar, a number of pines and other woods can be treated to improve their usefulness. They could be used to release hard maple, oak, walnut and other more desirable but less available and costlier woods. In turn, these woods, too, can be improved.

"Tidewater cypress with pleasing grain, California redwood with its satin texture and warm red color, and our almost white cottonwood, matching the best bleached woods, are but a few of the examples of the many woods that may now compete on even terms with other species.

"Advantage can now be taken of the natural beauty of these species in spite of the inherent defects that previously limited their uses. Hardness, finish, strength, density and durability can now be contributed by the treatment and one may in the future enjoy new furniture—even floors—of beautiful woods that never before could be used for flooring or furniture. They will be difficult to mar and can be readily restored to their original beauty if damaged."

III

Fire broke out in a Madison, Wisconsin, lumber yard one morning in June, 1944. Few merrier playgrounds for the fire demons are to be found than a well-stocked lumber yard. Here, besides large quantities of well-seasoned dry lumber, were many tons of coal which caught fire. Three companies of firemen did their utmost.

By the time the blaze was extinguished three hours later, one building 120 x 80 feet had been destroyed. The coal shed, stores of millwork, three trucks, and a considerable part of the lumber stock had been turned to ashes and charred debris.

Fifty thousand feet of other lumber, stored in the midst of the consumed material, remained unburned. The ends and exposed sides of the piles were charred a little. The flames had not taken hold.

That was flame-proofed lumber. Treated with phosphatic chemicals, it would char a little but would neither flame nor glow, despite the terrific heat which had surrounded the piles. So far there is no such thing as fireproof wood. Flameproofing, fire retardant treatment, however, is pretty good—good enough that ordnance plants, airship hangars, synthetic rubber factories and railroad buildings have consumed huge quantities of it in recent years, and its use grows. The process has made wood a better material than it was when nature created it.

Another important chemical improvement of wood has to do with its preservation. Creosotes and various salts have been used for a long time. Improved results are being obtained with chlorinated phenols. Colorless and not objectionable to handle, these materials are carried in a cheap petroleum base such as kerosene. Water repellents may be included in the treating mixture. Electric poles and cross arms, fence posts and other exposed articles have been improved with this new chemical preservative.

IV

A forest of trees that reaches skyward with clean trunks two or three feet in diameter is wealth in an obvious form. Anyone with a sawmill can make them into lumber, and for lumber a market always exists.

William H. Mason, once an associate of Thomas A. Edison, saw no mighty tree trunks in the forests around Laurel, Mis-

CHAPTER XV

Animal Chemurgy

I

LIGHT as a feather! When language first reached the metaphorical stage the feather no doubt became the symbol for lightness, almost as soon as the sun became the symbol for brightness. One feather is, indeed, trifling in weight, but every fowl sprouts several feathers, and fowls are numerous. The total weight of the feathers discarded from the chickens killed each year in the United States is estimated at one hundred million pounds, while turkeys add another thirty million pounds. Sixty-five thousand tons of feathers! Sixty-five freight trains of fifty cars each would do well to haul the load if twenty tons could be packed into each car.

The railroads obtain no such traffic in feathers, however. No jobs are made by this huge store, for all of them go to waste, except ten or fifteen million pounds that, for a nickel a pound, go into cheap pillows. Farmers get their poultry money from the eggs and meat.

So lamentable a state of affairs science will ere long relegate to the archaic past. On the desk where this is written lie swatches of fabric made from chicken feathers. The United States Rubber Company, which created the fabric, says it is "designed for use in suits, dresses, sweaters and other wearing apparel of the future." Chicken feathers are to become fine feathers for milady.

Since most chickens and turkeys leave the farms alive, to be dressed for market in a central plant, their feathers are not, like many agricultural wastes, too widely scattered. They are conveniently concentrated for industrial utilization. Concentrated feathers, however, have long been a nuisance. The birds are picked wet, and wet feathers decompose with unpleasant rapidity.

The situation was resolved when chemists set themselves to think it over and to try a few logical possibilities. Their ideas worked. One recipe is 0.55 of a pound of salicylic acid, 1.1 pounds of benzoic acid, and thirty gallons of lukewarm water. Another is 15 pounds of common salt and a pint of hydrochloric acid in the same proportion of water. Feathers so treated were shipped across the continent and back without decomposition.

Feathers, like hair, nails and horn, are protein substances. These are called keratin proteins; keratin derives from the Greek word for horn. A fibrous molecular structure characterizes these proteins. Long-chain molecules are extended and locked linearly. They resist ordinary acid and alkali solvents. Chemists at the Western Regional Research Laboratory found that a detergent (sodium alkyl-aryl sulfonate in water solution) is the solvent for keratin.

In the present state of knowledge, the quills are discarded after the barbs—the portions which branch off from the quill—have been removed. The chemical detergents dissolve the barbs; about two-thirds of their weight is recovered in the form of a heavy syrup. Then the liquid is squirted through spinnerets, the same as in the making of rayon or nylon, and is formed into threads which in turn are spun into yarn. Three-quarters of the feathers from a fowl, and 80 per cent of each feather, are usable.

According to Dr. W. A. Gibbons of the U. S. Rubber Company, "The new fabric looks like wool and it is warmer, softer and lighter than wool. It can be dyed any color and possesses a brilliant lustre. It is odorless and can be laundered in soap and water with no more shrinking than cotton. The feathers are particularly adaptable for admixture with other staple textiles, such as rayon, cotton, wool and nylon. The feather content of fabric used in the laboratory experiments ranges from 60 to 70 per cent."

As this is written, the whole feather utilization matter is still in the laboratory stages of perfection. With the new preserving treatment assuring large supplies of feathers, commercial operations can not likely be remote.

How many chickens will you need for a suit? For an average-sized man, thirty-eight broilers; for a woman's suit, size 18, thirty broilers. Ten such chickens will yield a pound of feathers.

Other uses are in prospect. Stitching of a more intimate character than that in a suit of clothes is a possibility. Surgical sutures of all-protein thread would be absorbed eventually by the body, making removal unnecessary.

The dissolved feathers have been molded into plastic materials. Dyes are easily absorbed by the plastic. These and many other chemical utilizations are under experiment. The processes with other protein materials are fairly well understood. Finally, the market for feathers will be determined by the qualities of the products made from them, and whether buyers will prefer feather-protein products to others which compete.

II

The chicken, said a negro philosopher, is a wonderful bird. "You kin eat him befo' he is bawn an' after he is daid." And that is not all.

The embryo chick, in the shell and half-hatched, has been put to work in the interest of human health. The egg, with the embryo in the process of growth, serves as an almost perfect sterile medium for the cultivation of virus.

A virus, unlike bacteria, which flourish in broths, can be cultivated only in living cells. The embryonated egg meets the requirement as nothing else does.

Eggs from half a million hens were collected during 1945, under scrupulous sanitation, to become hosts for the viruses of influenza and typhus. Experimentation continued to discover other comparable utilizations. Poultrymen were paid a premium of fifteen cents a dozen over market prices to produce eggs that were perfectly clean.

The process, therefore, begins in the laying houses and with the laying flocks. White Leghorn hens are preferred because dirt is easier to discover on their white eggs. Flocks are tested for pullorum disease, to insure strong and healthy embryos. Houses receive special cleaning, nesting material is watched with care to insure cleanliness, and eggs are collected more frequently. Since fertile eggs are necessary, the laying flocks are liberally supplied with roosters, which is not customary where market eggs are produced, since infertility is then preferred.

At the hatchery the eggs are reinspected for cleanliness, candled to eliminate those with bloody specks, graded so that only those weighing twenty-three ounces or more per dozen are set in the disinfected incubators.

For eight to eleven days, according to the virus intended to be grown, the eggs are incubated. Another candling then eliminates infertile eggs. Trucks, heated to maintain the incubator temperature so that embryos will remain vigorously alive, rush the eggs to immaculate biological laboratories. In the east, where nearly all this business is conducted, the distance is seldom more than seventy-five miles.

Dentists' drills puncture small holes in the air-cell end of the egg and with needles the virus is implanted in the embryo. Paraffin seals the hole, and for forty-eight hours incubation is continued.

At that stage technicians armed with tweezers break off the top of the shell, open the membranes and withdraw the embryo which has become thoroughly infected with virus. The embryo develops not only the infectious material but the antigen also. After a series of highly technical processes during which the infectious material is destroyed, ninety doses of influenza vaccine will have been produced from each one hundred eggs. The vaccine was regarded by the army as effective to at least fifty per cent.

The business of providing embryos in eggs to laboratories began in a small way when vaccines were developed by this means for combating sleeping sickness in horses and poultry laryngotracheitis. After years of research the production of influenza and typhus vaccines greatly expanded the demand. The egg embryo is regarded as a promising means for diagnosis of human and animal diseases, and may eventually be in substantial demand for that type of use.

Several hatcheries have held contracts to produce 120,000 partially-hatched eggs a week. This, in turn, has kept several large poultry flocks busy laying eggs for a distinctly non-food use.

III

A great deal more than the cackle goes to waste in the chicken business.

For instance, not all the eggs that are intended to hatch do hatch. That fact has been observed so universally that "Don't count your chickens before they are hatched" is a folk-saying from long ago. A conservative estimate a few years ago, before the war-time expansion of the industry, figured that ten million dozen infertile eggs and eggs with dead embryos were being cast aside at the commercial hatcheries. This waste amounts to a fourth or more of all the eggs which are set. Little or nothing has been done to utilize this easily available body of raw material.

Then nature persists in producing fairly equal numbers of males and females from the eggs that are hatched. Poultrymen, knowing that roosters lay no eggs, are willing to pay substantially more for pullets than for cockerels. Feed costs considerable money, and they do not like to feed a chicken several weeks just to find out that he is going to grow up to be a rooster. Meanwhile the art of "sexing" chicks has developed to such perfection that skilled workers can rapidly sort out the sexes right after hatching. So pullets are sold separately to grow into laying birds. Many, but not nearly all, of the unfortunate males can be sold to broiler producers. Consequently, huge numbers of cockerel chicks are destroyed soon after hatching. Yet nature has taken the trouble to produce and hatch the eggs and to create a young bird full of glands and proteins and only a chemist could determine what else. The bird ought to be good for something.

Poultry slaughterhouses where birds are drawn before being stored, canned or quick-frozen, yield a waste in offal equal to about twenty-five per cent of the live weight. This amounts to many thousands of tons. Little commercial use has been attained, although here again is a large and available quantity of materials with inherent values. The endocrine glands in chicken heads, for example, might lend themselves to valuable medicinal recoveries. Leg tissues may yield gelatin or products for surgical use.

The egg is one of nature's most perfect and most economical food packages. Nevertheless the package of shell and membrane contributes about ten per cent of the product. In breaking plants where millions of eggs are processed, the challenge of the shell demands a higher utilization than for chicken feed and fertilizer.

The chicken is indeed a wonderful bird, and undoubtedly there are more wonders in him and her than man has yet turned to his profit.

IV

After the American cow yields her milk (120 billion pounds a year), after all the milk bottles are filled for the fluid market, after all the cream is skimmed away and all the whole condensed milk has been canned, some sixty billion pounds of skim-milk remain. A fourth, perhaps a third, of this skimmed remainder finds commercial utilization. The calves and the pigs and chickens make good use of the rest.

Whoever can bid higher than the calves and pigs, will find around forty billion pounds of skim-milk available for feeding factories rather than young livestock.

Long before chemurgy became an organized idea, casein was a commercial product. By natural souring, by adding rennet or a mild acid solution, curd is precipitated from the skim-milk. The curd is readily processed into casein. Plastic items, such as fountain pen barrels and combs, have long been made from casein. As a glue it found extensive use in plywood, especially before the superior soybean glues were created. As a binder casein is a common ingredient in coldwater paints. Tons of it are used as a coating for smooth-surfaced papers.

Italian scientists conceived the idea that since casein is a protein substance, a fiber comparable to wool might be derived from it. Italy is a wool-deficient nation, so they were encouraged by the Fascist autocracy to carry through the research. Their product was exhibited at the New York World's Fair in 1939 under the name of Lanital, and efforts were made to introduce it into American commercial channels. Either it was not quite good enough to catch on, or the Italians began to see other more urgent uses; at any rate, lanital quickly disappeared from commercial vision.

The National Dairy Products Corporation, however, had heard about and admired the idea and was pretty sure there could be money in it. Thomas I. McInerney, then the president, who is not an Italian, doubtless decided that if Italians could make a fairish fiber out of milk, Americans could make a better one. The task was assigned to F. C. Atwood, head of the Atlantic Research Laboratories at Newton, Mass. In 1941, within four years of the start, commercial production was initiated. The American casein fiber was christened Aralac.

How can a fiber be made from milk? Casein is converted with chemicals into an emulsion that can be forced through spinnerets and stabilized into a fiber. The material does not duplicate wool, although it possesses several of the qualities of wool. Commercially it is spun with cotton, rayon or wool into varied types of yarns, or mixed with wool or rabbits' fur to produce excellent felts. Being light, warm and easily draped, Aralac has become especially popular for interlinings. Blending with rayon has resulted in several attractive new kinds of fabrics for clothing, ankle sox, robes and neckties. It adds warmth to rayon and cotton. At a time when people are conscious of being plagued by a multitude of allergies, Aralac can claim to be completely innocent of creating allergic response.

Like all the synthetic protein fibers, Aralac's wet strength is poor. The good qualities seem nevertheless to assure this milk fiber of a definite market for the purposes to which it is adapted. The price has been around sixty-five cents a pound.

The casein yield of whole milk is about three per cent. Four states, Wisconsin, California, Minnesota and New York produce three-fourths of the American output. This output varies, having been 67 million pounds in 1937 and only 47 million pounds in 1941. The total consumption is much larger. Argentina exported enough to the United States to provide for a total consumption here of 89 million pounds, nearly twice the domestic production.

About half of the total supply was consumed in paper coatings, about a fifth in adhesives, about one-twelfth for paints and plastics, and about four per cent for making Aralac.

Casein production has to compete with other dairy uses for raw material, and has to compete with scores of other products for places in the market. The output could be much larger if the economic demand required that more of the skim-milk be directed into casein, for the skim-milk is available.

V

Milk contains sugar as well as fat and protein. The sugar is lactose. It is neither very sweet nor readily soluble; about one-sixth as sweet as sugar. Nevertheless its characteristics have been pronounced unique and valuable; the fact that upwards of 120 million pounds are made yearly would appear to confirm the fact that it has value. Lactose found its first large uses in baby foods and pills.

Derived from lactose is lactic acid, which was first found valuable in baking powders, for controlling acidity in fermentation industries, and in the manufacture of bread. Made also from other sources, lactic acid finds uses in the tanning industry, in making acid beverages, and in phenolaldehyde resins, all of which seem far removed from the cow.

Fundamental research in milk proteins and solids remains to be done on an extensive scale. No one yet knows all that milk and its products are good for.

VI

More than sixty years ago the meat packers first began to hire an occasional chemist. The packing industry is essentially a food business. Yet the medicinal output alone, but one of the several non-food aspects, has been reliably estimated to total, in retail sales, at least fifty million dollars a year. Nor does the dollar value begin to express the real service.

"Hundreds of thousands of diabetics owe their lives to insulin," the Tenth Annual Chemurgic Conference heard Dr. David Klein say. "Who can evaluate in dollars the chemurgic value of this one product? Insulin has been known for at least twenty years, but it has not been synthesized. Its complexity, due to its protein nature, is too much for the present state of our chemical skill. Before its use for insulin, the pancreas had a very limited usage and a low market value. My estimate is that during the past twenty years the value of raw pancreas from the United States inspected abattoirs was $15,000,000 greater than it would have been had insulin not been discovered."

Describing the uses of animal glands recovered during meat processing, Dr. Klein, who is with Wilson and Company, presented several striking figures.

"Once in a while some one refers to these as by-products," he said. "Frankly I do not like the term. It has an unfavorable connotation, of something of low value, of minor importance. I submit to you that when a part of the animal has a commercial value considerably above that of the choicest beefsteak, it must be regarded with great respect; and not demeaned with the lowly term by-product. The market price of raw pituitaries is between $1.50 and $3.50 per pound, depending upon the species, beef being the cheapest and sheep the most expensive. Beef parathyroids cost anywhere from $5 to $10 per pound, depending upon their quality. To be sure, there is not the tonnage of these as there is of the commonly edible portions. Yet I would direct your attention to the liver.

"Time was, within the lives of those of us who will admit the years, when the butcher would throw in a piece of liver free, for the cat, with a purchase of meat. Those were the days when liver was figured on the basis of its tank value, about one-half cent a pound. Now, pork liver has a carload value of about 14½ cents per pound, beef liver about 30 cents. Figures were not available, but my guess is that at least 30,000,000 pounds of liver are used annually in this country for the preparing of medicinal products."

The more important abattoir sources of medicinal products are the pituitary, thyroid, parathyroid, suprarenal, pancreas, liver, stomach, male and female gonads. A dramatic illustration of the achievements of scientists utilizing extracts from these glands and organs appears in the treatment of Addison's Disease, described in the dictionary as a "chronic, fatal malady." Says Dr. Klein: "Persons suffering from Addison's Disease can be kept alive for years and in an economic state of usefulness . . . It may require ten cubic centimeters of an adrenal cortex extract daily to maintain certain patients. For this, one needs the glands of thirty-seven cattle. In the 10 cc. there is only 1/75,000th of the weight of the original glands."

Scientific expenditure in the packing industry has been steadily enlarged as the discovery of new values has demonstrated the profitability of research. Moreover, as a chemurgic conference in Omaha was told by Armour's director of research, Dr. Victor Conquest:

"Just about every product produced from inedible raw material is meeting more competition from a use standpoint than ever before. This competition eventually will seriously affect the credits expected from by-products. The meat packer must, for self-preservation and the preservation of the long established economic balance between prices paid for livestock and prices paid for the edible products by consumers, work to find more profitable uses for more of his by-products."

The far-reaching nature of packinghouse research was indicated by Dr. Conquest in the same talk when he spoke of the organic chemistry of the inedible animal fats. His remarks justify a full quotation. Here it is:

> These fats will continue for a long time to be used in the old standard operations of soap making and lubrication. They have great possibilities, however, in the production of a long line of fatty derivatives that have not heretofore been visualized. This type of research can very well produce new products for new and unheard of uses that will parallel the well known story of derivatives from coal tar.
>
> . . . In preparing fats for their chemical manipulation they need to be separated into the fatty acid and the glycerine portions. For some uses the fatty acids need to be separated into the several constituents making up the mixture as found in the animal. This can be done by fractional distillation under high vacuum. After separation into reasonably pure fractions, the particular physical characteristics of the individual components are apparent. Some of the fractions, such as stearic and palmitic acids, have high melting points. Others, such as oleic and linoleic acids, are liquid at rather low temperatures. Chemically, they may be divided into saturated, or the high melting, and the unsaturated, or the liquid fatty acids.
>
> For a large number of uses these products are satisfactory as they are. The stearic or palmitic acids go very largely to rubber compounding and lubrication. The oleic acid makes a better soap for textile uses, and the linoleic acid may become part of a paint oil mixture because it has some drying properties.
>
> These fatty acids are starting materials for products with such names as nitriles, ketones, amines, amids, polymers and conjugates. You do not care what the chemical structures of these products are. You will be interested in knowing what uses they might have. To mention some of these will let you see the variety and also some of the possibilities.
>
> They are suitable for and are going to these uses:
>
> 1. Rubber placticizers, natural and synthetic.
> 2. Hard and soft waxes.
> 3. Rainproofing for textiles.
> 4. Soapless soaps.
> 5. Coatings for papers and packaging materials.
> 6. Specialized lubrication.

7. Plastics.
8. Substitute rubber.
9. Minerals recovery through flotation.
10. Anti-corrosion materials.
11. Insecticides and insect repellents.
12. Fungicides and germicides.
13. Metal coatings.
14. Quick-drying oils.
15. Wetting agents.
16. Rubber reclaiming.
17. Emulsions.

Not many of the above uses are obtainable with the fat as it is produced by the meat packer. These new products and uses are a result of intensive, long-time research. The job on fats has hardly started and an increasing attention is due them from the meat packing research laboratories and others.

After commenting upon the better-known utilizations of hair, hides, bones and wool, Dr. Conquest states sharply that whatever has been accomplished in animal chemurgy, it is yet far from the possibilities or far from being enough:

> The meat packer has a large problem on his hands in the better and more profitable utilization of protein by-products . . .
>
> This can be accomplished by proper support of research and development, by wise, practical and informed expert direction toward the objectives, and by complete cooperation in the fundamentals of chemurgy.

VII

Furs are a luxury universally desired by women and in some occupations a necessity for men. They have always been expensive. The potential demand has never been satisfied, for furs never have been cheap enough to come within the reach of vast numbers of eager consumers. Furs are not food. While chemurgic organization has given little attention to promoting their production, the field is logical and ripe for attention.

Fur farmers and trappers are paid some sixty million dollars a year here in the United States for their output. The nation imports twice as many furs as it produces. Here is the largest fur-consuming market in the world, where in a single year retail sales have reached half a billion dollars.

Yet there are some things no one knows about the wild animals which produce furs, nor about those which are raised in captivity for their pelts. A student in the field might well ask:

Are the trapping seasons correct to insure a harvest while promoting the increase of animals?

How can the several species of fur bearers be restored and multiplied in the wild?

Could artificial insemination, now widely practiced in the dairy industry, be used to reduce costs and improve stock among mink, silver foxes, or other fur animals kept in enclosures?

What is there to learn about feeding to insure health, desired qualities of coats with the preferred colors, sheen and density?

Can the carcasses be utilized to better advantage?

Why do many species fail to flourish at all in captivity?

These are but a few of the more obvious questions. That captive fur production can be further developed is indicated by the success of silver fox producers. The two largest fur farms in the world are located in Wisconsin, with more than 8000 breeding pairs on each.

Louisiana, with her large muskrat production, is the largest fur-producing state of the forty-eight. Not too much is known about the muskrat, and many of the marshes and swamps where his hides might be harvested are barren of his presence. Muskrats might well be a regular winter crop on thousands of farms.

The fur demand has lately resulted in the production of a handsome coat for women, made by subjecting sheepskins to special shearing and treatment. Called Mouton by the trade and selling under $100, it signals the range of opportunity that may be developed with adequate knowledge of animal life.

It may not be out of place here to remark that no new animal has been actually domesticated within historic times. The horse, cow, sheep, pig, dog, cat, camel, elephant and probably the reindeer were at the service of man before he learned to keep records or even to save his legends. A few economic species such as the fox and mink have been subdued to survival in captivity; some have been transplanted into new areas. I have several times talked about this with Frank Buck of "Bring 'Em Back Alive" fame. He has suggested that the mouse deer, the tiny fellow of the Malayan regions, or some of the African antelope species, might lend themselves to experiment. Good eating, anyway, he says. Vilhjalmur Stefansson was recently quoted as hinting that the musk oxen might be taught to flourish in New England; they would need no barns in a Maine winter.

CHAPTER XVI

Fruits from New Branches

I

THE surprise of the character whose reading suddenly revealed to him that he had been a biped all his life and never had known it, was not much greater than the surprise of some of the cranberry growers of Massachusetts. They discovered that they had been producing ursolic acid all their lives and not only did not know it, but neither did anyone know what ursolic acid might be good for.

The creation of a dump has seldom been profitable to those who provide the materials. Ever since cranberries had been graded and shipped fresh, many tons of the inferior berries had been thrown away. From the time the bright idea of canning cranberry sauce grew into an industry, more tons of waste pulp, skins and seeds found their way to the profitless dump.

The chemurgic idea that plant substances may be coaxed to reveal countless hidden values was not overlooked on Cape Cod nor by the shrewd men interested in the cranberry business in southeastern Massachusetts. They set themselves up a research laboratory. Here Dr. Walter A. Nealy started to work on the idea that the bright red color of the cranberry might very well yield a pigment that would possess marketable industrial values. He thought that if he could only isolate the pigment into a fairly pure form, then it would be possible to study its properties. He wanted to know how it would behave when heated, when exposed to metals and to the atmosphere.

The work on pigments was impeded by a resinous substance which at first was regarded as "just another of those substances often encountered when working on plant products." Nevertheless there was something intriguing enough to bring attention back to it from time to time. Dr. Nealy finally found that what he had seemed to be crude ursolic acid. He sent some to the only man he could learn about who had ever given any attention to ursolic acid. That was Dr. Charles E. Sando of the U.S. Department of Agriculture. Sando confirmed the identification, said there had never been enough of it produced to make it a commercial item, and that what little there ever had been had commanded a very high price. Mention of a very high price was not to be unnoticed by Massachusetts Yankees. The Research Department of Cranberry Canners, Inc., set out in earnest to recover enough ursolic acid to be able to examine its values. They have found out quite a bit.

When refined, ursolic acid becomes an exceedingly fine and very fluffy white powder. A pound of it occupies about 231 cubic inches. It is tasteless, odorless, insoluble in hot or cold water, and has no acid reaction. It is not poisonous. It is soluble in alcohol and benzene and in some other organic solvents.

One interesting property is the behavior of the stuff as an emulsifying agent. If three parts of ursolic acid are placed in a mixture that has one thousand parts of the other ingredients, the droplets of water will assume positions suspended in the oil. This reverses the customary event when an emulsion is produced, where the oil is suspended in the water.

Cold creams and cosmetics of various types may very well adopt this cranberry product as one of their ingredients.

The glossy coating on the bright red skin of a healthy cranberry is a mixture of ursolic acid and a waxy material. This coating has so high a melting point that little if any of it is removed when cranberries are boiled in water.

By governing the solvents and temperatures used when extracting, waxes of varying degrees of hardness and varying melting points may be obtained. The waxes promise to be acceptable for a number of industrial uses. Mixed with softer waxes, their melting points, for instance, may be raised.

Cranberries also have seeds, and within the seeds is an oil, about one-fifth of the weight of the seeds. That's good, too.

Several Massachusetts doctors have been prescribing a preparation created by the cranberry laboratories, which is a mixture of distilled water, ursolic acid, cranberry wax and cranberry seed oil. They find that under the treatment soreness disappears almost immediately from burns and that healing progresses with remarkable rapidity.

Eleven different products, six already known to have commercial values, have been recovered from the waste material that for a long time went to the cranberry dumps. Plans were ready at war's end to proceed with a large by-product plant the moment materials and equipment could be purchased.

The cranberry has neatly and heartily endorsed and proven the chemurgic thesis.

II

The citrus industry once had nothing to sell but whole fruit. Since only the best of the fruit could be shipped to the distant locations where most of the markets were found, a substantial proportion of inferior fruit and culls returned no profits to the producers.

Scientific approaches have changed this situation until now few of the fruits or parts of the fruits fail to find an economic use. Year by year means are found to extend the separation of by-products and to refine the wastes to still higher values. The California Fruit Growers Exchange maintains a highly organized citrus laboratory at Ontario. The Florida Citrus Commission collects two cents per box of oranges, three cents per box of grapefruit, and five cents per box of tangerines. The proceeds go into a fund for promoting and extending the use of Florida citrus; the fund amounts to $1,250,000 and upwards annually. Five per cent of the fund is set apart for scientific research. Texas and Arizona also have provisions for research, and the four states are represented on the Citrus Products Research Council, an organization of the scientists engaged in studies of the citrus crops.

The first step beyond the marketing of fresh fruit was to can the fruit and the fruit juices. This has expanded until in Florida 68 per cent of the grapefruit and 34 per cent of the oranges are canned or made into canned juices.

Since only 45 per cent of the orange or grapefruit is juice, the processors were faced with the question of what to do with the other 55 per cent, which is peel, rag and seed. Feed for livestock has become the largest outlet. Twelve plants in Florida manufacture feed from the citrus wastes, with an output in 1945 of 75,000 tons.

Cattle, however, are content with what is left after a few other ingredients are taken out. One of these is an oil, pressed and refined from the peel. This finds a market for flavoring ice creams, gelatins and other desserts and in flavoring preparations. One year's total output of peel oil from Florida alone reached 350,000 pounds.

A product of the feed manufacturing process is the press liquor which flows off as the moisture content of the waste is being reduced. Containing about 8 per cent solids, this is concentrated under vacuum into citrus molasses, similar to blackstrap molasses, and finds itself later as another ingredient in stock feeds.

Another recovery is distilled orange oil, which in turn is usually refined to limonene, a substance which has a variety of uses in chemical industries.

A major by-product of citrus processing is pectin. Present apparently in all fast-growing plants, pectin is extracted more easily from the white inner part (called the albedo) of the citrus rind, just inside the colored outer oil-bearing portion. Apple pomace is another source, although apparently not so economical. The best known use of pectin, of course, is for making jellies, since it has the property of combining with sugar to make fruit juices jell. For this purpose it has long been on the market.

Recent years have seen an extensive development of pectin in medical fields. Intestinal disorders, such as colitis, diarrhea and bacillary dysenteries are treated with pectin. It has some values for the control of bleeding. For shock treatment, especially where blood plasma was unavailable, it has proven useful. Pectin also serves as a basic paste for carrying such substances as sulfa drugs, ammoniated mercury and boric acid.

In still another form, a pectate pulp aids the oil industry in drilling wells. Mixed with mud, it helps to prevent water loss into porous strata. As a paper coating, to prevent sticking of packaged synthetic rubber, it found a new use in a new industry.

Quite different in properties from ordinary pectin are the modified (low methoxyl) pectins. These have found a large use for jelling low sugar and low acid products such as canned mixed salad fruits, tomato juice and even canned consommé. A variety of dessert preparations are made with this form of pectin, which promises to create a considerable addition to pectin consumption. During the war army field rations included more than 24 million cases of low-pectin jelled mixed fruit.

That pectin is already a substantial by-product industry is indicated by the fact that some ten million dollars' worth of it, in various forms, is produced and sold by the California Fruit Growers Exchange.

Wherever a fruit industry concentrates its yield for packing or processing, there is likely to be an opportunity for recovery of additional values. The economic fact of place is highly important. Scattered over thousands of acres of orchards and groves many miles apart, culls can not be worth much. Brought together in substantial tonnage, they afford opportunity for utilization. At concentration and processing points, too, are accumulated residues after the valued food portions are removed; these go less often to the dumps as enterprise seeks out their values.

A Texas company has marketed monthly a tank-car load of bland oil extracted from the wastes of a pecan shelling plant. The oil is found in the shells, inner partitions, and broken bits of kernels. Pharmaceutical companies buy it. Years ago the California Walnut Growers began grinding their shells to a flour which found a market, among other places, in the manufacture of electric batteries, and has since found other uses.

The wine industry is the source of some twenty or more by-products. A. M. Paul of Fresno has built a substantial manufacturing business on the lees of the wine vats. His principal product is cream of tartar. The concentration of grapes for wine also yields materials for leather tanning, ink manufacture and ethyl alcohol. The oil from grape seeds is pressed out and sprayed on raisins to prevent stickiness. It may be polymerized for paints or turned, as are most other vegetable oils, to soap manufacture.

The pits of apricots, prunes, peaches and cherries all yield oils, some of which is recovered and refined for pharmaceuticals, face creams and sardine packing. Peach and apricot seed shells, like walnut shells, are sometimes ground into a flour, and also are made into absorbent charcoals. Apricot kernels, processed into a paste, have largely replaced almonds as the base of the distinctive flavor in macaroons.

Apple sirup, an orchard by-product of expanding importance, is described in another chapter. Even the oil which makes up one-fourth of the weight of apple and pear seeds is attracting interest, although so far no commercial development has appeared; and the waxy coat which lends to apples and pears their attractive shine, may one day be separated from the rind and put to use.

III

Hides are a by-product of animal husbandry, or of the meat business, as one chooses to view them. Leather, the product of hides, demands tannin and that is a vegetable item.

Once the bark of oak and chestnuts yielded tannin in cheap abundance. As the chestnuts disappeared and oak became more scarce, the tanners searched for other sources. Chrome salts provide a mineral tanning process which does very well for light leathers, such as shoe uppers, but shoe soles and harness and heavy luggage leathers still demand treatment with the vegetable tannin. A substantial source has been the hard, ax-breaking quebracho tree of the Rio de la Plata region in South America. The Western Regional Research Laboratory has sought to improve the tannin yield from the bark of hemlock, still abundant in the northwest. Sumac is one of the more abundant tannin-bearing plants, but this wild shrub has never yet proved itself economically worthy of domestication. A number of desert shrubs have been investigated.

The tanning industry, incidentally, uses other products of the soil besides leather and tannin. Among these are eggs, casein, soybean protein, beef blood, tallow, corn sugar, beeswax, hulls from corn, peanuts, cottonseed and soybeans, and some vegetable oils.

A stable domestic source of tannin in sufficient quantities is still sought.

CHAPTER XVII

The Subject of Alcohol

I

THE wit who described the five stages of drunkenness as "jocose, bellicose, lachrymose, morose and comatose" apparently possessed but a limited idea of the range of reactions which may be stimulated by alcohol. Alcohol is a fluid of controversy in more senses than one. However, as an industrial material of top-rank importance, it deserves treatment on the strictest level of fact.

Most conspicuous as the intoxicating agent in fermented and distilled beverages, alcohol has so many other uses that "drinking liquor" belongs in an almost minor category. Beverage alcohol reported in a pre-war fiscal year totalled seventeen million proof gallons; ethyl alcohol for industrial purposes, 244 million proof gallons.

Alcohol is logically a topic of high interest to farmers because it can be made from sugar, or from the starches which are easily converted to sugar. Starchy grains and tubers are abundantly produced. Corn, wheat, barley, rye, grain sorghums, sweet and white potatoes are always potential sources of alcohol. Since they tend to fluctuate severely in price, alcohol as an outlet is naturally viewed as highly desirable.

The dimensions of the present alcohol market are huge. The variety of uses is immense. Used for heat and power and light, as a notably versatile solvent, an antiseptic, a reaction medium and a manufacturing ingredient, alcohol appears in so many forms of consumer goods that the average pre-war per-capita amount of two gallons seems hardly enough. Not very much may disappear in the manufacture of strychnine or tincture of nux vomica, but anti-freeze uses it up fast; a little alcohol will go a long way in straw hats, but a little will make a poor start at supplying the demand as a solvent for nitrocellulose, or as a solvent for dyes, oils, or lacquers.

Normally the pre-war raw material for alcohol was molasses, the by-product of the Cuban sugar plantations. Cheap, abundant, and fairly stable in price, blackstrap neatly filled the specifications of the manufacturers. Chemical economics gave it the preference, and the facts of chemical economics dictate what material shall be preferred. But chemical economics change as facts change; and, moreover, there is no prohibition against trying to nudge chemical economics.

II

When the Farm Chemurgic Council was organized in 1935, agricultural prices generally were low and grain "surpluses" were conspicuous in discussion. Francis P. Garvan, president of the Chemical Foundation and president of the Council, had become persuaded that the use of a percentage of alcohol in motor fuel would answer the surplus problem. He launched two efforts to nudge economics. One was directed toward arousing public opinion to demand that ten per cent of alcohol should be blended with gasoline. The other sought by research to turn up new facts that would remove any question as to the economic feasibility of the program.

In answer to contentions that the blends would not work, Garvan produced advertisements by American-controlled companies, praising alcohol-gasoline fuels which were distributed in England and other countries. He used the platform and press to keep the controversy warm, not failing to take full advantage of whatever errors of strategy or tactics his opponents committed.

Meanwhile through the Chemical Foundation Garvan advanced funds for the purchase of an old alcohol plant at Atchison, Kansas. Here he hoped the research organization, headed by Dr. Leo M. Christensen, could prove his case.

The Atchison Agrol Company was charged not only with research but with immediate manufacture of anhydrous (water-free) alcohol and with distribution of blended motor fuel in the nearby area. The research effort contributed some advances in production methods, despite the handicap that Christensen and his associates had to divide their energy among research, manufacture, and sales. The undertaking left no doubt in the minds of several thousand motorists that a gallon of fuel, of which a tenth was alcohol, would run a motor car very satisfactorily. It did not succeed in proving that alcohol could be produced cheaply enough to share a portion of the market with the gasoline which petroleum chemists simultaneously were improving and producing more cheaply.

A by-product of the Atchison experiment was a conviction, lodged in the minds of large numbers of Nebraska, Iowa and Kansas farmers, that further effort might well in some manner produce alcohol outlets that would tend to stabilize grain prices. Suggestions were advanced that it might be sounder to subsidize the use of alcohol in motor fuel than to subsidize restriction of acreage; or that, by lowering the tax on motor fuels containing alcohol, blends might be enabled to hold a share of the market.

The Fourth Annual Chemurgic Conference was held in late April, 1938, at Omaha. The alcohol-motor fuel controversy was still aflame. Appearing for the first time as president of the Chemurgic Council, I faced the necessity of making a decision. Would the interests of farmers be served by keeping the controversy going, and heightening hopes which might conceivably not be sustained by events? Or would the wiser course be to insist that facts, and facts alone, be permitted to determine the outcome? The decision was announced in the opening address of the Conference:

"I am personally opposed to establishing power alcohol's use through legislation. While conceivably the social results might justify such action, it were better that the fuel should succeed on its merits, for then its place would be sound and permanent.

"If power alcohol is right, nothing on earth can stop it. If it is wrong, no subsidy or tax differential can establish it permanently. Let's insist that research shall develop the facts."

Excessive emphasis upon the power-alcohol idea had not been without disadvantages to the growth of the Council. One effect had been to divert attention from the fundamental breadth of chemurgy's philosophy. Alcohol is one industrial outlet for farm products, and a very large one; future demands may make it much larger. However much alcohol consumption in its many forms may expand, the need for intelligent development of other new uses, and of new crops, will not disappear. No one single outlet will ever consume all the agricultural materials not required for food.

III

Pearl Harbor precipitated another alcohol controversy. The imperative necessity of immediate, large-scale production of synthetic rubber, at any cost, found the United States ill-prepared. Industries had failed to receive any encouragement in previous years when they suggested that, for defense purposes, they should be aided to prepare the country with stand-by processes. Few believed, of course, that natural rubber supplies would ever be unobtainable. No visible synthetic process could promise to compete with natural rubber prices. Practically none was being manufactured, except Du Pont's Neoprene which was snapped up regardless of price because it possessed qualities that natural rubber does not have, such as ability to resist the action of oil and grease.

Butadiene, the essential chemical compound with which synthetic rubber manufacture had to start, could be made from petroleum. Also, it could be made from starch by way of ethyl alcohol. The new controversy centered on whether the oil industry should receive a monopoly in butadiene production, or whether farmers should be permitted to participate. The storm centered principally around the War Production Board, the Rubber Reserve Company and the Rubber Director's office. With quantities of critical materials necessary to build the new plants necessary for either approach, these officials were on the spot to decide between oil and grain.

Considering the imperative need for rubber, the choice was to provide butadiene from both sources. Events fully justified that course. Petroleum experience was so slight, so little advanced beyond laboratory stages, that unforeseen difficulties arose when full-scale production was attempted, difficulties which delayed and reduced the output. Rubber Director William Jeffers was quoted afterwards as saying that without the alcohol produced from the grain plants the invasion of France could not have been accomplished at the time it was.

Three large new alcohol plants were built, at Omaha, Muscatine and Kansas City. War needs also led to the suspension of beverage spirits production while the distilleries were set to making industrial alcohol.

IV

The end of the war put no period to alcohol controversy. Rather, the door was left open for argument embracing wider considerations.

The future of the synthetic rubber industry itself became one basic question. Should the United States utilize the opportunity to become independent of foreign sources for so vital a commodity, excepting for whatever natural rubber might continue to be essential?

This problem admitted emotional and political approaches as well as discussion on purely economic grounds. The consideration properly in the foreground was the national defense. Adequate preparation for defense obviously could not permit sole reliance upon natural rubber, whether it be produced twelve thousand miles away in the East Indies or four thousand miles away in the Amazon Valley.

Then should the entire synthetic capacity be kept in operation, or only enough to develop our skills and provide a partial supply? There were those who believed the British and Dutch should not be deprived of a restored share of the world's biggest rubber market, in the United States. There were others who believed that domestic synthetic production should not be permitted to occupy a market that might partially be supplied by natural rubber from South American neighbors.

Against these considerations stood the demand for high employment in the United States and the necessity of a vastly heightened level of national production and income. Would it be better to maintain full production of synthetic rubber in order that the national economy might benefit from the jobs the industry would supply?

Again arose a former question. Should the butadiene or other basic materials be produced from grain or from petroleum? If from alcohol, should the alcohol be made from grain or from petroleum gases? The oil industry believes it could produce cheaper alcohol from waste ethylene gas than grain could supply. Yet, the ethyl alcohol field being crowded and highly competitive, and the capital investment for this process being very large, would the oil men prefer to carry their alcohol on into more profitable end products?

Suppose grain surpluses again should become formidable. Would it be cheaper, from the standpoint of the nation as a whole, to subsidize conversion of grain into alcohol than to turn, as likely would be done, to other forms of "relief" for the grain producers?

Still another grave question of national policy, another question on which experts fail to agree, confronts those who seek to discover the right course. How much petroleum does the United States really have available, under its own soil or elsewhere? Would it be in the national interest to conserve oil by substituting to some extent the annually renewable materials derived from agriculture? Some of the experts are pessimistic as to the extent of petroleum reserves; others profess to see no occasion for taking alarm.

Then, what of changes in technology? Gasoline for motor fuel has tended to become cheaper because of improved methods in refining and distribution. Will a time come when nothing further can be done, or when scarcity of crude petroleum turns the price upward again? Will alcohol production become cheaper? Will a rising cost of gasoline some day cross the alcohol price line, and thus remove the question of comparative economy? Present day motors do not use all the power in gasoline. Will changes in motor construction bring about new conditions under which alcohol will make a new contribution to fuel efficiency? Alcohol injections in airplane motors during the war were used to avert icing of carburetors and to produce more effective power under certain flying conditions. The German V-2 robot bombs were powered with eight hundred gallons of industrial alcohol and liquid air.

The technical arguments against alcohol to produce power have grown fewer and thinner. Remaining are the economic considerations; and, then, the political considerations. Apparently no one has yet proved that the two and one-half to two and three-fourths gallons of alcohol obtainable from one bushel of corn can be made cheaply enough to compete with gasoline; that is, when the price of the bushel of corn is fifty cents, or more, a bushel. No one yet considers corn production economic at a figure much under that.

Guesses have been made that some other crop than corn, yielding a larger quantity of starch per acre, or costing less to plant and produce, might afford agriculture a better toehold in the alcohol picture. Jerusalem artichokes, dahlia tubers, and sweet potatoes have been among the possible crops discussed. So far no sufficiently comprehensive operation has been undertaken to determine the accuracy of the guesses.

During the war the Omaha and other plants consumed corn, oats, wheat, rye, barley and grain sorghums. Whether the experience has netted any new or decisive facts about costs of production remains to be found out. The first objective was not low-cost alcohol but large quantities of alcohol.

The by-products are a factor in the cost. When corn reaches the plant it is ground. The alcohol all comes from the starch, of which there is about 30 pounds in a bushel of corn. The ground corn is mixed with water and cooked for six minutes. Then barley malt and yeast are mixed in and left to ferment for 48 hours. The crude beer which results is eight per cent alcohol. The alcohol is distilled off. Remaining are all the proteins and oils that were originally in the corn—unless the germs have been floated out after grinding, in which case the oils would be recovered. The residual material, in any event, mixed with the malt and yeast, is excellent livestock feed, and contains except for the starch as much value as was in the original bushel of corn. Corn fed without protein supplements is wasteful because the carbohydrate, or starch, is out of balance.

The value of the by-product feed is high. It fluctuates somewhat in the competition with other feedstuffs, but probably less so than corn itself. Another possible by-product is dry ice, which can be recovered if suitable equipment is installed. The demand is heavy in summer but falls off in winter to such a degree that the actual gain is difficult to calculate.

Six pounds of butadiene, incidentally, result from the alcohol output of one bushel of corn, and that makes about six pounds of synthetic rubber, approximately the quantity in one ordinary tire. Thus one bushel of corn plus twelve pounds of cotton or other fabric, plus other chemicals and a great deal of skilled know-how, equals one tire.

Industrial alcohol finds it ways into the manufacture of more than 300 different products. At any time a new development in some sector of chemical industries may call for a spectacular increase in demand, as did synthetic rubber. Certain types of plastics, for instance, require alcohol in their processing. The appearance of a new factor in price or process, such as would give one of these plastic types a large preference, would result in a correspondingly larger call for alcohol.

As long as molasses is available in sufficient quantities, it will no doubt be preferred because of its low and fairly stable price. One difficulty respecting corn as raw material for alcohol, not previously mentioned here, is that the range of price from year to year, sometimes even from season to season, is disturbing to the purchasing agent of a chemical industry. Nevertheless the starch industry manages to operate despite these fluctuations, and perhaps alcohol could also manage to exist with them.

Should the expansion of the chemical industry, or rather of the chemical industries, create a demand for alcohol that far outran the molasses supply, a new set of conditions would confront the alcohol portion of the chemical economy. Alcohol, without doubt, would be made, and it would have to be made from something. It would be made from something plentiful, and from the least expensive of the plentiful materials.

Probably only when the facts of research and the realities of economics can be assessed, in the light of their relationships at one future time or another, can definitive answers be determined for a few of the questions which, in the meantime, will no doubt continue to be agitated in the alcohol arena. But the decisions will be made by facts of some kind, whether they be economic, political or chemical facts.

V

Normally the term "industrial alcohol" is taken to refer to ethyl alcohol, made from sugar, molasses or grain. Other alcohols, however, voraciously consume farm products and are highly important in industry.

One of these is butyl alcohol, or butanol, to which your automobile owes its shining coat. Butyl alcohol is a powerful solvent which cheerfully wades into cellulose and reduces that substance to a condition that facilitates the manufacture of quick-drying lacquer. Automobile manufacture is measurably accelerated by the quickness with which modern lacquers can be dried. Where days were once required to spray or dip a car body in successive coats of paint and wait for each coat to dry, the job now is done in hours. Further, the finishes are superior in quality and present consumers with a wider variety in color choice.

Clostridium acetobutylicum is the name of the hired hand who produces butyl alcohol. Unlike the yeast fermentation of ethyl, butyl is a bacterial fermentation, and *Clostridium acetobutylicum* is the name of the specific bacillus that knows how to turn corn into this particularly powerful solvent. He eats up millions of bushels of corn each year.

The exciting story of this bacillus has been told often enough elsewhere without need of a full repetition here. Briefly, during the 1914-1918 War, Britain was in desperate need of acetone. It was essential for explosives and airplane dope. Dr. Chaim Weizman, the Zionist leader who is a top-ranking chemist, knew this bacillus would produce acetone. Hastily snatching up distilleries, the British solved their problem. Among the distilleries obtained were one in Terre Haute and one in Peoria. After the war, Commercial Solvents Corporation took over these two plants. Promptly the bottom fell out of the acetone market. But, for every pound of acetone the process made, it made two pounds of butyl alcohol which had been piling up in storage tanks looking for a job. The motor industry's demand for a new lacquer provided the job, so Commercial Solvents cheerfully kept the bacillus busy. Acetone found uses in artificial silk and leather, photographic film and other products. Besides butyl alcohol and acetone, portions of ethyl alcohol, methanol carbon dioxide and other chemical values are recovered.

VI

The author of a recent book was worried about chemurgy. He feared that it would carry away so completely the products of the land that nothing would be left with which to restore the soil; nothing, that is, of the organic matter derived by nature's syntheses from the sun and air and rain. Perhaps these few words from Dr. Paul Kolachov, consulting chemist located in Washington, will help to ease such alarms:

The fermentation industry works in a continuous cycle, giving back to the soil in the form of fertilizer all the minerals and vitamins it has taken out, so that the soil too can continue to live. If we utilize farm crops for food only, what will we do when all the elements are exhausted from the soil? By developing the fermentation industry, in which the by-products are used an animal feed and thence as fertilizer, we can avoid this dilemma, which is sure to come at some point in the future.

CHAPTER XVIII

American Farm Rubber

I

THE invasion of Normandy on the scheduled day was made possible, according to the statement of William Jeffers, director of the wartime rubber administration, by alcohol fermented from the corn and wheat of the Missouri Valley.

When their successes in the Far East enabled the Japanese to shut off the shipment of natural rubber to the United States, they stood in a fair way to win their war. Sixty per cent of the world's rubber is consumed in the United States. Rubber was simply indispensable to the production of war materials and to civilian activities. Rubber was indispensable to the machines of war. The invasion mounted on rubber even before the Normandy beach heads were captured.

The Japanese triumph in the rubber plantations was nullified by American science. Before Pearl Harbor the laboratories had acquired more than a glimmering of know-how toward production of synthetic rubbers. Neoprene, highly resistant to oils and chemicals, had already been marketed by the Du Ponts, who were making it principally from acetylene and nitrogen sources. Knowledge of other types had been built up, samples had been made, but the cheapness of natural rubber and the unwillingness of the government to encourage synthetic development at home had prevented development on commercial scales. The know-how was theoretical, and untested in full-scale plant production.

Pearl Harbor blasted into the consciousness of industry and government the overwhelming immediate need for vast quantities of butadiene. The synthetic rubber that came to be known as the GR-S type, needed in the largest quantities because it was the rubber for tires, required as its principal ingredients three parts by weight of butadiene to one part of styrene. Styrene is made by combining ethylene and benzene, products of petroleum. Butadiene can be produced from the hydrocarbons of petroleum or from industrial alcohol.

Government authorities decided to make sure of butadiene by authorizing the construction of plants for both the petroleum and the alcohol processes. The petroleum people encountered seemingly endless troubles. The big plants were built and built fast, but somehow the processes that worked promisingly in the laboratories and even in the pilot plants, refused to perform according to plan on the larger commercial scales. Everyone knew there was a war on and that time was of the utmost essence. No effort was spared, and eventually the difficulties were solved and the flow of raw material to the rubber factories mounted to great figures.

Meanwhile, plenty of people knew how to make industrial alcohol. Give them something to ferment and the equipment to ferment it in and that item they could produce. Happily the alcohol displayed no disposition to be stubborn about being turned into butadiene. Long before the petroleum plants got under way, rubber from alcohol-butadiene was being turned out in tires for the army's trucks and varied automotive fighting monsters.

So, the rubber was ready for D-day on the beaches of Normandy, and no small part of it was rubber that once had been wet corn in the fields of Nebraska or second-grade wheat on the prairies of the Dakotas. Farmers began to let their hopes rise toward the vision of a permanent new outlet, or at least one that would skim the surplus grains from the markets in years of excessive production or insufficient demand.

The present fate of that hope is curtly set forth in the Interim Report of the Surplus Property Administration, January 14, 1946, which says:

> "The high cost was due in large part to the considerable use of butadiene made from alcohol. Alcohol butadiene was much more costly then petroleum butadiene and raised the cost of GR-S accordingly. The use of alcohol butadiene has ceased and the three plants which manufactured it for the Government synthetic program have now been shut down."

Alcohol butadiene, a hero on D-day, finds at home an economic future clouded by the lesser cost of a competitive material. The imperious need of the hour for alcohol in huge volume, at any cost, doubtless prevented a full-scale endeavor to determine the minimum possible cost of alcohol butadiene. Nevertheless, the oil wells, rather than the farms, appear to have the preference in the present status of facts. The hope refuses to die, however, in the knowledge that change is one of the habits of economic facts.

II

A basic economic fact, ever a changeable one, is the fact of how badly people want a given product and how much they will pay for it. Those who control the supply of a given product are sometimes tempted to discover what the maximum price, thus determined, may actually be.

The average price of rubber back in 1910, when the plantations in Malaysia and the East Indies had not caught up with the rapidly-growing American automotive industry, was $2.06 a pound. The yearly averages thereafter, through the first world war, were $1.41, $1.21, .82, .65, .66, .48, .36, and then in 1921 a low mark of 16½ cents. The figures are for plantation-ribbed smoked sheets at New York.

Thinking happily of the decade before, when Americans cheerfully had paid more than two dollars for a pound of rubber, and being, undoubtedly, grateful for American military and financial assistance during their years of war travail, the British and Dutch imperialists in control of the plantations thought up an idea which came to be known as the Stevenson Plan. The idea was, simply, that no matter how much rubber was grown, only as much should be exported as would keep the supply a little short of the demand. The scheme worked beautifully for a while. During 1925 the price averaged 72½ cents, and for a time touched $1.12. Americans paid, but were no longer cheerful about it. Infuriated by the hold-up, Herbert Hoover, then Secretary of Commerce, organized programs for reclaiming used rubber and for obtaining supplies from uncontrolled sources. The imperial monopolists finally acknowledged defeat and before the end of 1928 folded up their plan.

During the world depression rubber prices fell disastrously, along with nearly all others. By 1937 they were up again, above 19 cents. During the war the price of natural rubber was controlled at 22½ cents. Synthetic rubber, GR-S, was fixed at 18½ cents, which was regarded as a comparable price, since the cost of processing GR-S was about four cents per pound more than for natural rubber.

With the end of war, new questions arose regarding the future of rubber. Many of these questions were complicated by considerations of national and international policy.

Synthetic rubber capacity had been built up to more than one million tons per year. Presumably the productive ability of the Malaysian plantations would be restored, and their owners would again wish to supply the American market. Quite likely they would be willing to undercut synthetic costs if they could. Then, the techniques known at the close of the war continued to require, particularly for the larger sizes of tires and for some other uses, a proportion of natural rubber to be blended with the synthetic materials. Meanwhile, production of natural rubber had been encouraged in the other Americas.

No one could forecast the probable consumption of rubber. That it would exceed the pre-war annual totals of around 600,000 tons, appear reasonable to suppose. That it would exceed those figures by the possible amount of synthetic production, appeared unlikely.

Should the United States think first of future national defense and hereafter produce the maximum quantities required from the nation's new synthetic capacity? Does the national defense also demand that the pre-war rubber imperialisms be sustained by imports, and that the production of the other Americas continue to be subsidized?

Should the nation also be guided by a cheap rubber policy, buying natural or synthetic according to which cost least? Or should thought be given to the jobs at American-scale wages which could be maintained by continuing at full-scale the synthetic manufacturing enterprises? After all, the rubber workers on foreign plantations never had wages enough to become customers for tires, nor even for raincoats or overshoes. Their regions bought only about forty million dollars worth of goods from the United States in return for three hundred million dollars worth of rubber alone.

One answer certain to emerge was that in the search for synthetic formulas and for rubber substitutes the laboratories found dozens of rubber-like compounds. Among these are several that will move into the hands of consumers to perform functions for which rubber formerly was used but for which the new substances are definitely superior. For others of these rubber-like substances there may be found needs which had never been supplied before. It will be difficult to tell in many instances, too, where plastics leave off and synthetic rubbers begin, or vice versa.

Still to be determined is the part the products of agriculture will play in the future of rubber and related materials.

For instance, there is guayule.

III

Guayule is a low, grayish-green shrub that looks not unlike sage. In the American Southwest and in Mexico it grows native in dry desert lands. Indians long ago found that by chewing it they could obtain a resilient substance that would bounce when pressed into a ball. At the Centennial Exposition of 1876 in Philadelphia the State of Durango exhibited the shrub and its product, hoping that capital would come to Mexico for its exploitation. None came because no suitable extraction method was known.

Eventually processes were developed. Small quantities of the wild rubber was extracted from time to time. The resin content was high, and the rubber was generally used only where tackiness was desired. The Intercontinental Rubber Company was organized about 1911. A young scientist, Dr. W. B. McCallum, set to work to study guayule in the wild and to experiment with its cultivation. In 1930 the company built at Salinas, California, a mill capable of turning out 10,000 pounds a day. During the four runs the mill made in the ten years following, it processed the shrub from 4400 acres and produced 3,068,630 pounds of crude rubber. Meanwhile Mexico continued development, producing some 20,000,000 pounds in 1944.

When the war rubber emergency arose, those who knew about guayule thought immediately of the desert shrub as a natural rubber source. Legislation was hastily drawn for surveys, one of which discovered more than five million acres (5,651,000) north of the Mexican border to be suitable for growing the crop. Half of this was uncleared brush pasture on the Texas plains. The government took over the Intercontinental properties for $1,721,235. These included 1483 acres of land, 674 acres of growing shrub, the mill, 22,867 pounds of seed, 14 million seedlings and other assets.

Congress first authorized that 75,000 acres be planted. A little later the authorization was raised to 500,000 acres. New research was launched. Then, only a few months later, a decisive curtailment of the program was ordered by the Rubber Director. In all, about 32,000 acres had been planted. A little less than a thousand tons of rubber had been produced by the end of the war; estimates were that 15,000 to 25,000 tons were contained in the growing shrubs that had been planted. Then Congress ordered liquidation of the entire project.

The liquidation proceedings contemplated paying 18 cents a pound, the ceiling price, for such rubber as was to be harvested, and plowing under the remaining acreage that had been planted. California farmers exploded against the proposals. They pointed out that under the deal with Mexico the Government would pay 31 cents a pound for all the guayule shipped from there up to June 30, 1947. With the national stockpile still low, imports still uncertain, and a free market willing to pay them more than 50 cents a pound, these farmers objected to seeing the Government spend $9 to $15 an acre to liquidate the already growing guayule by eradicating the shrubs from their lands.

Among those locally familiar with the California experience were many who believed that the guayule crop might, with a little encouragement, find a sound place in their agricultural economy. The hasty wartime research efforts had reduced the cost of gathering seed from a dollar to a nickel a pound. Normally the harvest consists of digging the entire shrub from the ground, after which new plantings become necessary. Tests, however, had indicated that merely mowing the tops off would collect about two-thirds of the rubber-bearing material, and that the pollarded shrubs would then grow new tops if the operation had been performed at the right season.

Possibilities were still left in the culture of higher-yielding varieties, in further studies both of dry land and irrigated land cultivation, and in further mechanization. Emphasis is placed upon the fact that guayule is one of the few field crops, if not the only one, that does not require harvesting at a given period nor even in a given year. If left unharvested, the shrub continues not only to grow but to store up rubber. Thus it might be planted on cheap lands and left to grow for harvesting only in the years of most favorable prices.

The paid destruction of the already-planted shrubs, certainly appeared to trangress common sense. It was reminiscent of the days of plowing under cotton and killing little pigs, though not analagous, because the prospective needs for natural rubber were well beyond the supply.

A consequence of the precipitate liquidation of the guayule project is the loss of an excellent opportunity, already well advanced, to know with some precision what might be accomplished with the shrub. The question is left hanging. The actual costs of production are not determined. The range of possible cultivation is still guesswork. The determination of best varieties and the chance for better varieties are left open. The further adaptability of machinery is left unstudied. Nor has the guayule rubber itself had too good a chance to reveal the extent of its usefulness.

Thus no one now knows with certainty what is the place of guayule, if any, in the agricultural economy of the dry southwest. Another war would find the country almost as unprepared to develop a natural rubber program as in 1941, if natural rubber should still be required. No one yet knows that it will not be.

What is known is that the southwest can produce from guayule a natural rubber of certain usefulness; and that, by

Government decision, neither the people of the United States nor the farmers of the southwest are supposed to learn more about it than is already known.

On the unknown list also is this: What influence determined the Government to make the liquidation decision?

IV

Whether or not the tale of the Russian dandelion is a success story depends entirely upon one's definition of success.

Late in the nineteen twenties a statesman, possessed of a somewhat higher degree of economic literacy than is common in that profession, approved a plan. The statesman's name, which later became better known, was Josef Stalin. The plan was simple. Rugged young men and women from the farms of Russia were to be taught well in botany and given some enlightenment in other sciences. They were to be told a little about the needs of their country and what to look for. Then they were to go out over the steppes, into the mountains, through the valleys and swamps. Their eyes were to be alert for every plant which might conceivably have an economic value. True, Russia was known to produce nearly everything, except rubber and cocoa. Perhaps they could find the foundation plants for better strains of crops already cultivated. Rubber, everyone knew, came from a tree that grew only in the tropics and Russia had all climates except the tropical. Still, the American literature had mentioned that milkweeds and goldenrod contained rubber. Who knew that somewhere on eight million square miles a young explorer might not find even a plant that would yield rubber for Russia?

Not all the details are known, but no unusual imagination is needed to guess that every species of milkweed and goldenrod, every leaf, stalk or root whose wounds emitted a sticky latex, was examined with eager scrutiny. The hardy young botanists sent quantities of seeds and tubers, cuttings and whole plants, to the central experiment stations at Moscow.

One party, pushing into a wild and sparsely peopled region close to the remote Chinese-Turkestan border, came upon a vigorous kind of dandelion. The plant and roots were thick and heavy. The roots were of enough interest to send samples and seeds of the plant to Moscow.

Moscow's scientists agreed that here was a plant worth their study. Plots were devoted to multiplying the supply. This was early in the thirties; the plant was called kok-saghyz (just say "coax-th'-geese").

The roots did yield rubber; not very much, but rubber nevertheless.

The plant breeders went to work. Seeds were dispatched to stations in the Ukraine, in Crimea, and even up north of the Arctic Circle, to be grown under every possible condition. Reports were published in the Russian scientific press.

In time the reports were read in Washington. Requests for some of the seed were forwarded to Russia from the Department of Agriculture. Seeds eventually arrived. They would not grow. Of course, ways to sterilize seed are known, ways that do not alter its appearance. Frequently, too, seeds kept too long in tightly closed containers lose viability. That they would not grow may have been accidental. The matter could be forgotten, for its importance was small. Rubber from the British and Dutch East Indies was cheap enough.

By 1936 the Russian scientific papers said that as much as fifty pounds of rubber per acre were being obtained from new strains the geneticists had found. That, too, was of little importance; only seven dollars and fifty cents an acre, at fifteen cents a pound, if the farmers got it all. What farmer could raise dandelions for that, when American crops grossed an average of twenty dollars an acre?

Then in the early spring of 1942 an idea was born one pleasant day during a hearing before a Congressional Committee. I had some months previously outlined a bill embodying certain proposals which I believed to be urgently important. The bill was to provide for research to discover and develop new crops for American farmers. A man familiar with legislation for the experiment stations had put the ideas in proper bill form. Representative August H. Andresen of Minnesota had introduced the bill, after Representatives Fulmer of South Carolina and Cannon of Missouri had declined to do so. A hearing on the bill was being held by the Committee on Agriculture.

Among the witnesses invited to support the bill was a brilliant Russian-born organic chemist, Dr. Paul J. Kolachov, who gave the Committee a long list of plants which he thought might possibly become crops for American farmers. Most of them were being grown elsewhere in the world and their products imported to satisfy American needs. He exhibited an array of samples.

Questioned by friendly members, Dr. Kolachov mentioned the Russian dandelion. Yields under best conditions, he said, had been as high as two hundred pounds of rubber per acre.

Why would it not, asked Dr. Kolachov, be a good idea for one of the members of Congress to urge that the Secretary of State request Russia to reverse our then new Lend-Lease idea and send some kok-saghyz seed for trial in the U.S.

Representative Andresen promptly sent a vigorous letter to the Secretary of State. A voice from the Department of Agriculture's precincts remarked that a yield of fifty pounds of rubber per acre was not promising. The suave Dr. Kolachov did not suggest that the Department might be four or five years behind with its reading of the Russian scientific literature. A few weeks later, before the end of May, one hundred and thirty-nine pounds of the seed arrived. They had come by airplane, with assurance that larger supplies were enroute by sea. The seed was turned over to the Department of Agriculture.

As usual when a job to be done is actually in their hands, scientific administrators in the Department acted with both celerity and good judgment. Although spring was nearly over, seed was rushed to the forty-eight state experiment stations. Plantings were made in more than sixty different locations. Enough experience was gained to form a preliminary estimate of the adaptation of Russia's dandelion to American climate and soils. The larger consignment of seed was in hand in time for 1942.

The country was at war, and eventually a Rubber Director was appointed. One of his acts was to order that the facts be determined about kok-saghyz. The dandelion roots from the experimental plots were shipped to Philadelphia, where the Eastern Regional Research Laboratory was ready to take on the job. The results, in the cold and matter-of-fact terms of official language, are told in the 1944 Annual Report of the Bureau of Agricultural Chemistry:

> A simple, practical process was developed for recovering rubber in good quality and good yield from either fresh or dried kok-saghyz roots. A pilot plant for carrying out this process was designed and built, and about 4000 pounds of kok-saghyz rubber was produced.
>
> Standard physical tests in the Eastern Regional Laboratory and in the laboratory of a large rubber company showed kok-saghyz rubber to be of very good quality—intermediate between guayule and hevea. About 3000 pounds of the pilot-plant rubber were to be fabricated into all-kok-saghyz tires by two large rubber companies. These tires, ranging in size from 9.00-20, 10-ply truck tires to 6.00-16, 4-ply, passenger-car tires, were to be subjected to exhaustive laboratory and road tests.
>
> On the basis of pilot-plant operations, it is estimated that a factory costing $1,880,000 and operating 300 days per year would extract an average of 10 long tons of kok-saghyz rubber per day, and would serve a planting area of 39,800 acres net. The cost of

extracting the rubber, without credit for byproduct and including amortization and everything except the cost of growing, harvesting and transporting the roots, would be 11.7 cents per pound. Such a factory could turn out annually a quantity of byproduct sirup, suitable for fermentation to alcohol, containing 6,350,000 pounds of sugars; the value of this byproduct would represent a credit of 2.5 cents per pound of rubber, which would make the net cost of extracting the rubber 9.2 cents per pound.

Assuming a yield of 400 pounds of commercial rubber per acre, which probably could be attained by several years of additional research on breeding and cultivation of high rubber-bearing strains, it is estimated that a smaller factory costing approximately $1,360,000 could turn out 10 tons of rubber per day at a net cost of about 7.4 cents per pound instead of 9.2 cents. The planting area required would be only 16,800 acres net. About 4,000,000 pounds of sugars per year would be produced, and the average credit would be 1.5 cents per pound of rubber.

Since the harvesting seasons cover only one month in the spring and one month in the fall, the necessary root-storage facilities to permit operation of the factory throughout the year are included in all the above figures.

Information accumulated in the course of pilot-plant experiments suggests that further experimentation would make possible material reductions in the estimated costs.

If an undertone of suppressed enthusiasm seems to sound in those paragraphs, perhaps the facts are responsible. The figures given bear a bit of analysis and projection. It may first be remarked that in instances where their processes have been subjected to commercial production experience, the cost estimates of the Regional Laboratories have been proved to be notably accurate and on the conservative side.

The first estimate does not mention yield per acre. However, the annual output of 3000 long tons divided by the planting area indicates that the yield basis assumed here is a fraction under 169 pounds per acre. Reports on the field experiments have not been published. This calculation indicates that yields of from 150 to 200 pounds of rubber must have been proven in the very hasty experiments with the Russian seed.

The second estimate, which assumes 400 pounds per acre, would not have been put into an official report if it were merely some dreamy scientist's idle guesswork. There was unquestionably a solid basis for assuming such a yield under American conditions. The reference to "several years" is, to any one familiar with government report writing and editing, a protective qualification added, probably not by the original writer, to make the story safe from critical attack. This second estimate sets the cost of processing the kok-saghyz rubber from 16,800 acres at 7.4 cents a pound. Why the by-product is worth a cent less per pound in the second estimate is not clear.

Suppose foreign rubber again becomes as cheap as the general pre-war price of 15 cents a pound. Kok-saghyz processing cost of 7.4 cents would leave 7.6 to the farmers who planted and harvested the crop. A 400-pound yield would bring $30.40 per acre gross return, or about 50 per cent more than the average pre-war normal gross from all crops.

The 400-pound yield would require 5.6 acres to grow one long ton (2240 lbs.) of rubber.

At that rate the 600,000 tons of normal pre-war consumption could be grown on 3,360,000 acres. That would employ a little more than one per cent of the total crop land harvested in the nation, which is 321,242,000 acres. A million tons, which may more nearly approximate our postwar use, could be grown on 5,600,000 acres—and leave the country 315 million acres for other crops. A few years ago the talk was about restricting farmers so as to take forty million acres out of production.

However, the 400-pound yield is apparently only an estimate of a future possibility. The one we seem to be safe to assume as already experienced is 169 pounds. That would require 13.25 acres to produce a long ton of rubber, or 13,250,000 acres to grow a million tons. Quite a little land would still be left on which to raise bread and butter.

The price level after the war, according to many presumptions, will be higher. Suppose common sense prevails and the United States determines not to depend on the Malay area for rubber again. Surely the synthetic rubber industry will not be entirely extinguished. Suppose also that the kok-saghyz yield remains at 169 pounds, which costs 9.2 cents to process. And the rubber price is not 15 cents but 25 cents a pound. In that event a 169-pound yield would bring $26.70 per acre if the farmer got all the difference. (Some allowance must be included for transporation and handling.) If 169 pounds are within reach now, no doubt hope exists that higher yields and more profitable farm returns would follow serious attention to the problem.

One more combination before we pass! Assume a 400-pound yield and then the 7.4-cents processing cost . . . and 25-cent rubber . . . 17.6 cents margin, or $70.40 an acre before manufacturing.

Idle figures, perhaps. Of course they may mean that an important new crop could be added to American agriculture with an assured domestic market for the product. A few thousand good, solid American jobs might be created. The United States and every automobile and truck owner might be assured of an ample, continuous rubber supply that could be threatened neither by Oriental wars nor by such a British-Dutch scheme as the Stevenson plan, which squeezed the American price up to $1.12 a pound (let's see—$1.12 less 7.4 cents processing cost, leaves $1.046 for farm production which, times 400 pounds yield, equals $418.40 per acre to farmers who would grow the Russian dandelions to—thunder, only a British or Dutch capitalist rates than kind of an income.

so let's drop this whole thing before anyone at home gets crazy ideas).

The Office of Rubber Director gave orders that the $150,000 pilot plant at the Eastern Regional Research Laboratory should be shut down by June 30, 1944. The experiment stations were told not to bother any further with kok-saghyz. They could resume their concentration on better and cheaper methods to grow more wheat and cotton and corn than we know where to sell; and of course the machinery to restrict acreage awaits in the federal sheds.

The kok-saghyz experiment was a failure. Or was it?

There is no need to say more about the Russian dandelion with the queer name.

Or is there?

V

The hard fact of cheaper butadiene from petroleum apparently bars farmers from selling raw materials for synthetic rubber. The liquidation of the guayule project by the roots has been ordered by Congress. The virtual extermination of the kok-saghyz experiments has been decreed. The immediate prospect of agricultural participation in the rubber business is not merely dark, but virtually nonexistent.

If all the facts about guayule had been developed and all the facts about kok-saghyz had been assembled, and if neither had then offered any genuine economic promises, the situation might cheerfully be approved. As matters now stand, a blazing question remains. Clearly enough, when war demanded that every spare effort be concentrated on the conflict, the suspension of experimental programs, if they appeared needless or fruitless, was proper enough. But the war was over when the plow-up of growing guayule was ordered. The kok-saghyz research was far from complete, either on the growing plots or in the laboratories. It might have been suspended until the war's end, and then resumed until the facts were fully explored.

The question that flames forth, then, is whether these decisions are separate, isolated or accidentally similar, or do they form a pattern of some determination that rubber shall not grow on American farms? If the latter, whose determination? By what influences were the various decisions brought to conform to the single pattern? Who is so determined, if anyone is, that research looking to farm-grown rubber shall not advance a step further than it was compelled to go by the desperation of war?

No ready explanation of the pattern can be offered. If the pattern does exist, the rubber manufacturers can not be suspected; they displayed friendly interest in the experiments, and are entirely conscious of the enormous market a prosperous agriculture affords for their finished products. The petroleum industry is secure for the present behind its low butadiene costs. The British and Dutch imperial planters naturally would not like to see natural rubber grown on American farms; yet it would seem preposterous to suppose that consideration for them would take precedence in the places of authority over the interests of American farmers.

The question would dissolve if arrangements were changed so that the research into production and processing of guayule and kok-saghyz were continued. As long as appearances indicate that some one fears discovery of the facts, the question will continue to blaze.

Part Three

CHAPTER XIX

Government Takes a Hand

I

THE true story of how our government, more than a bit unwilling, came to appropriate a magnificent fund for chemurgic research, is more amusing than the versions that the public has been invited to accept.

The national and regional conferences all received generous treatment from the press and the radio. The news purveyors recognized an interesting new idea. They saw that important national and local names were conspicuous in the meetings. They sensed the presence of controversy. Whoever read the papers closely began to be conscious of chemurgy. Proceedings and papers were distributed extensively to prominent people. Where a seed might fall and sprout was unpredictable.

One of the seeds sprouted in the mind of the ambitious and less than universally-admired Theodore Bilbo, of Mississippi, in whose state a conference had been held. He told the people of his state that he would work for a genuine solution of the cotton surplus problem. He would get them a laboratory in which science would be put to work to find new and economical uses that would consume their cotton.

In the Senate Bilbo prepared to introduce a bill to establish a federal cotton laboratory in Mississippi. Fellow senators listened to his plan.

"You can't get that kind of a bill through," he was advised.

"Why not?"

"Simply because it is all for your state. Why should other senators vote to spend the tax money of their constituents to put up a building in your state just for your constituents?"

Bilbo was perfectly able to understand that language.

"Thunder! Then I'll introduce a bill to build forty-eight laboratories. I've promised Mississippi a cotton laboratory."

He consulted privately with agricultural research experts. Eventually a bill was drawn to appropriate four million dollars a year to build, maintain and operate four regional laboratories. One was to be built in the South, one in the North, one in the West and one in the East. Their purpose was to find new uses for agricultural products of which surpluses were produced.

The Farm Chemurgic Council does no lobbying and takes no part in legislative affairs. When inquiries were made by senators or others for facts bearing on chemurgic research, facts were supplied. The legislation was not discussed by the Board of Governors.

The bill passed both the Senate and the House and fell into the hands of a joint conference committee as an amendment to the Agricultural Adjustment Act of 1938. The committee, of course, was heavy with administration legislators.

At this point the story has a missing link which Senator Bilbo denies he can supply, and which no one who knows has been willing to reveal. Both houses had passed the measure and tacked it on to the A.A.A. bill with little discussion or opposition. After all, public support for new uses research had been clearly visible and no opposition to so obviously meritorious an aid to agriculture had appeared to exist. Suddenly the smooth course found a snag in the conference committee. Some of the members who had voted on the floor a little earlier in favor of the laboratories, were now against them.

A message had plainly arrived from a highly-influential source outside the capitol. Was it from the White House, or from the Secretary of Agriculture, or from a recognized spokesman of one of them? Whatever its origin, the burden of the message was: "Four million dollars is a lot of money to throw blindly into a new kind of research. We've got to think of the taxpayer. Wouldn't it be sensible to appropriate only, say, $100,000, to find out how you would use four million dollars in research if you had that much?"

The reasonableness of this message promptly persuaded the majority of the committee. They decided to save four millions for the taxpayers; they voted the $100,000. Caution, reason and economy held up their heads in triumph.

By some clerical error or other quirk, the conference report, when it reached the Senate floor, was not quite as intended. It provided for $100,000 to investigate and also four million dollars for laboratories. Possibly the committee had only informally decided against the larger sum and had neglected to make the action complete.

Bilbo's alert eye caught the situation immediately. He saw his chance to snatch victory from the jaws of defeat. On his feet instantly, he proposed the vote. Before the opposition realized what was happening, the four laboratories had become a legislative fact.

Some months later I was in the White House with a group of agricultural editors. One mentioned the laboratory plans favorably.

The President said he thought they were among the administration's most constructive agricultural acts.

II

The laboratories were located at New Orleans, La., Peoria, Ill., at Albany, Calif., across the bay from San Francisco, and at Wyndmoor, a suburb of Philadelphia, Penna. In addition to full laboratory facilities, provision is included at each of the four laboratories for pilot-plant operations where findings can be tested on a semi-commercial scale before being released.

Henry Wallace, who was then Secretary of Agriculture, spoke at the cornerstone ceremony of the Northern Regional Research Laboratory in Peoria, October 18, 1939. This quotation from his address may be of interest:

> "If we expect the fantastic dreams of the chemurgic leaders to be realized in the near future, then we are bound to be disappointed. But if we are patient and look farther ahead, we can expect helpful results from the work of the laboratories."

No one could entirely deny Mr. Wallace's jibe. Fanatics there were indeed among the supporters of chemurgy, and no doubt, too, those given to fantasy. Without the enthusiasts who had poured their time and money into a program they believed necessary to their country, public opinion would not have been sufficient to support the act of Congress which appropriated the money for the laboratories. The laboratories were no product of the administration's thinking or support. Mr. Wallace had a cornerstone speech to make because the "fantastic" chemurgists and supporters of chemurgy had created the occasion.

Each of the four laboratories cost, when completed, around two million dollars.. The appropriations for the first two years were consumed in erecting and equipping the buildings. Progress was threatened in 1939 when administration political forces, still keeping their fanaticism well under control, set out to whittle down the appropriation. They were successful. For the fiscal years 1940, 1941, 1942, and 1943, the fund was, respectively, only 3, 2, 3, and 3.5 millions. When it was restored for the next year, the chairman of the house subcommittee on agricultural appropriations, Representative Clarence Cannon of Missouri, who has scuttled more proposals for agricultural research funds than any other man, snarled at a witness: "We shall expect within ten years . . . commercial products . . . to justify this expenditure, and if not . . . the staff you are assembling and everybody connected with those farm laboratories should be in position to seek other employment."

The Bureau of Agricultural and Industrial Chemistry was assigned to oversee the planning and operation of the laboratories. The wise old Chief of the Bureau, the late Dr. Henry G. Knight, aided by a group of the men who were to become the nucleus of the regional laboratory organizations, handled the building task with masterful foresight and comprehensiveness. Visitors to the institutions and the scientists employed, join in admiration for the completeness and convenience. Indeed, so superbly was the planning and building job accomplished that those most responsible ought to be named. They were Horace T. Herrick, Wallace P. Van Arsdel, G. E. Hilbert, and four men who were to assume administrative direction of the laboratories, D. J. Lynch, O. E. May, T. L. Swenson and Percy A. Wells.

The Southern Regional Research Laboratory at New Orleans was assigned to investigate new uses for cotton, peanuts, and sweet potatoes.

At the Northern Regional Research Laboratory at Peoria were placed the problems of new uses for corn, wheat, and the search for profitable uses for agricultural residues.

The Western Regional Research Laboratory near San Francisco was put to work on alfalfa, fruits and vegetables, wheat and Irish potatoes.

The Eastern Regional Research Laboratory in Philadelphia was directed to study milk, apples, vegetables, Irish potatoes and tobacco.

III

Scientific research is one of the extremely few activities, other than police work, in which government has any proper business. This book is not the appropriate place in which to describe the correct and severely restricted boundaries within which government as the people's servant should be confined. The desirability of governmental expenditure for research, however, is clear. The basic reasons for this have seldom been better asserted than they were by the first president while preparing his last message to Congress; a speech, he said, "which, probably, will be the last I shall ever address to that, or any other public body." Writing to Alexander Hamilton, no longer in his cabinet but still a trusted advisor, George Washington said on November 2, 1796:

> "Whereas if they [the farmers] were taught how to improve the old, instead of going in pursuit of new and productive Soils, they would make those acres which now scarcely yield them anything, turn out beneficial to themselves, to the Mechanics, by supplying them with the staff of life on much cheaper terms, to the Merchants, by encreasing their Commerce and exportation, and to the Community generally, by the influx of Wealth therefrom."

Washington's message a month later urged a National Board of Agriculture "to encourage and assist a spirit of discovery and improvement . . . by stimulating to enterprise and experiment. . . . Experience accordingly has shewn that they are very cheap instruments, of immense National benefits."

Government research and education contravene no rights when soundly conducted to cause more needed agricultural products to be produced and utilized. They add to the total national wealth, and benefit all sections of society.

Opportunities for research abound in areas which are not tempting to the expenditure of private money. A large amount of agricultural research lies in such areas. A business composed principally of small units, as agriculture is, can not readily organize to collect funds adequate to accomplish expensive, highly organized research.

Even if this were possible, the results of research are not predictable. The benefits from the money so collected might prove to be larger for manufacturers or consumers than for the producers. For instance, corn growers produce each year a larger tonnage of stalks than of grain. The commercial market for the stalks is nonexistent where they are most abundant. If corn growers were to organize and finance research to make the cornstalks more valuable, one result might conceivably happen to be a new discovery for the utilization of lignin, a component of the cornstalks. But very likely lignin from wood could be obtained and sold more cheaply; so the lumber industry rather than the corn farmers would benefit from the research. Through governmental research, the costs can be borne by the entire people and the benefits, fall where they may, are eventually shared by the whole nation.

Then, too, private industry may have no temptation to expend funds in research for agricultural products. If all research were left to the companies that can afford the outlays necessary for its proper conduct, one inevitable consequence would be that the big corporations would continue to get bigger. Only they could afford to develop the new processes and discover opportunities in the existing raw materials. Even so, a century might pass before any corporation could see a good reason why it should investigate possible uses for cornstalks or risk its funds on a highly speculative and unpredictable piece of fundamental research which might yield results highly important to some one else but not to their own stockholders. Neither can venture money be often collected to do research on the ground that some profitable commercial opportunity may be discovered.

Nevertheless, private industrial research was immediately stimulated by the establishment of the four regional research laboratories. "We will watch everything you do and when it interests us we will try to get it done first," the research director of one large company told Dr. Knight. Dr. Knight promptly set up a plan for industry committees which work closely with the laboratories, to familiarize themselves with the work. Several industries have permitted their equipment to be used by the laboratory scientists for full-scale test runs. The test tube is checked by the pilot plant, and the pilot plant by the commercial-size operation, in order that every difficulty shall be corrected. The objective is always to perfect a process and to get it into commercial use with the least expense and delay. The regional laboratory workers are not ivory tower scientists; they are practical men.

IV

Criticism has been levelled at the regional laboratory policy for the very reason that the programs are practical.

"Why don't you stick to fundamental research?" the industrial scientists sometimes ask. "We can take care of the practical applications. Somebody has got to be increasing our body of fundamental knowledge. Who is in better position than the government?"

"We should like to do more fundamental research work," the laboratory men are likely to answer. "Only the Sub-Committee on Agricultural Appropriations demands that we produce practical results for immediate application."

One may wonder whether the repercussions of the atomic bomb have jarred the Clarence Cannons of Congress into comprehending that only fundamental research marks out the long steps in scientific progress. Fortunately, the regional laboratories, pushing for practical results on many fronts, at least have the chance that the accidents of research may occasionally uncover a new fundamental fact along with those which can be rushed to the patent office, the pilot plant and the factory.

V

Soon after the laboratories were completed and before they were fully staffed the United States went to war. The government found itself with eight million dollars' worth of new, strongly manned research facilities which had by no means been planned in advance as a necessary adjunct to the national defense. Virtually no official thought appeared to have been given to the economic aspects of defending the nation until the war was upon us.

Agricultural materials were of high importance for both food and non-food war purposes. The laboratory programs were immediately redirected to war problems. A literal fact is that no warship was launched, no airplane was flown, no tank or truck went to war, and no cannon was fired without agricultural products entering into its construction. In addition to feeding the workers and fighters, farm materials were also a prime necessity in the manufacture of explosives.

Food had to be conveyed in enormous quantities over great distances at a time when ships and cargo space were at a premium. Millions of pounds of dehydrated food reached our distant fighters because of improved methods quickly worked out in the western laboratory. The eastern laboratory came through with a sirup from cull apples, and thus met the civilian need for great quantities of the glycerin that went to war. The southern laboratory found a way to use cottonseed oil instead of imported palm oil for an indispensable process in the steel industry and in improved cotton tire-cord processes. The northern laboratory multiplied penicillin production by 200 times, besides doing other important work.

Their war accomplishments have unquestionably paid for the regional research laboratories and for many future years of their operation.

VI

The public funds invested in the Northern Regional Research Laboratory at Peoria paid the most dramatic dividend. They made penicillin abundant.

The outlines of the history of penicillin have become fairly familiar. Dr. Alexander Fleming, a microbiologist at St. Mary's Hospital in London, had published in 1929 his observation that spores of a soil mold, *penicillium notatum*, had proved destructive to certain harmful bacteria. Nothing much more had been done about it until 1939, when Dr. Howard Walter Florey at Cambridge remembered Fleming's experience. His staff, with great difficulty, made enough penicillin from the mold to sense its tremendous value. By 1941 they were pretty sure. But in England at that dark time no possible means was discoverable by which quantity production could be developed. Florey and his associates had made hardly more than enough penicillin to treat a half dozen patients and two of these, extreme cases it was true, had died. Two men came to the United States to see what might be done. They found themselves in Peoria on a dripping hot day in July of 1941.

Dr. Robert Coghill, Dr. Andrew J. Moyer, and Dr. Kenneth Raper headed the group that eventually included most of the laboratory staff. Moyer started to vary the diet on which the mold was multiplied, hoping to find something that would grow the stuff more rapidly. Routine procedure in all new fermentations is to try many materials. One on the list is corn steep-liquor, the left-over water from soaking corn preparatory to starch manufacture. The steep-liquor diet was the first that showed noticeable results, and these results were big. With the same amount of work, ten times as much penicillin could be obtained. Milk sugar was added and still larger yields were obtained.

Dr. Raper meanwhile was searching for other strains of the penicillia mold that would be more productive. He shortly had the Army Air Forces sending him packages of soil scooped up from spots all around the world. Patiently he tested the soil molds they conveyed to Peoria. He found an extra-good strain growing on a cantaloupe in a Peoria store. This culture, No. 1951, was doubly important. Not only was it productive but it would grow in a submerged solution. That meant the mold could be multiplied in tanks instead of having to be grown laboriously in bottles.

The net result of the Peoria researches was that penicillin production was multiplied more than 200-fold and the way opened to further advances which have increased production to as much as 400-fold. At least thirteen companies in the United States and Canada are now in the business and one of the most costly of medicines has arrived on drug-store shelves at prices within everyone's reach. More than twenty millions of dollars are invested in producing penicillin.

No true measure of this research achievement can be approximated or even attempted, for that would have to be in terms of lives saved, agonies prevented, illnesses cured. Burns and infections yield to it. Blood poisoning and heart infections are cured. Childbed fever is cured. Gonorrhea disappears within hours, as compared to days with previous treatments. It has been highly effective against syphilis. Mastoiditis and peritonitis give way before its power. Such results simply can not be tallied, but they have been properly hailed with mankind's admiration and gratitude.

The men at the Northern Regional Laboratory, the pioneers in England, and the industries that risked millions to hasten production when the process was uncertain and the possibility of profits remote, all share properly in the admiration and gratitude.

Penicillin is essentially a chemurgic product. The mold itself is one that grows in the soil. Corn steep-liquor and milk sugar, the principal constituents of penicillin's commercial diet, are products of the land.

VII

The regional laboratories were established with the idea that they would improve the nation's economic rather than its physical health. To the eastern laboratory was assigned the effort to find new values in tobacco, as well as in milk, vegetables, apples and Irish potatoes. Out of the tobacco studies came, unexpectedly, a medical product.

Rutin does not possess the wide range of curative properties that have made penicillin so dramatic. To those who suffer with hypertension, a heart ailment, it has a definite importance of its own. Rutin appears, after extensive clinical tests on human beings, to reduce the capillary fragility which results many times in the sudden extinction of life by what is usually called a stroke. It is believed to alleviate conditions which may result in apoplexy, easy bleeding, and retinal hemorrhages.

High-quality, flue-cured tobacco was found by the laboratory investigators to yield rutin. From low-grade tobacco, from stems, and from air-cured tobacco, little or none could be obtained. So the source of the drug was costly. However, enough was made for careful tests at the hospital of the nearby University of Pennsylvania. After indications appeared that rutin had a genuine medical value, other plants were examined to determine whether a cheaper source of rutin might be located. Previous literature had listed violets, forsythia, elder flowers and garden rue as plants which contained rutin as a constituent. The researchers happened to gather up an armful of buckwheat which was growing near the laboratory. That produced more rutin than anything previously known, and is now the preferred source. A ton of dried buckwheat plants will yield enough rutin to make a million tablets containing suitable doses of the drug. Five pharmaceutical companies are manufacturing rutin tablets.

Best known and most widely commercialized product of the eastern laboratory is a bland apple sirup. The cigarettes which are advertised as treated with "apple honey" contain tobacco in which this sirup is a moistening agent. Formerly glycerin was the principal material used to keep tobacco from becoming too dry to burn properly. The apple sirup was introduced just when war needs were demanding all the glycerin supply for more urgent purposes.

Apples which although sound are not marketable because of their shape or surface defects, are washed, ground and juiced. The juice is treated with hydrated lime, heated to 175°F., and clarified by filtering. It is then further neutralized by a mild acid treatment and is evaporated.

The resultant sirup has no trace of apple or other flavor. The color is light amber. The content is 75 per cent solids, there being usually 40 per cent levulose, 13 per cent dextrose, 14 per cent sucrose and 8 per cent of nonsugar solids.

The apple honey characterization is no mere advertising phrase. The sugars in the sirup are the same as those in honey, although not in exactly the same proportions. The Apple Growers Association of Hood River, Oregon, and four or more other companies manufacture the sirup. While glycerin is slightly better as a humectant, the tobacco companies which have invested in advertising the apple product are likely to continue to use it.

The process of synthesizing rubber requires, at certain stages, the creating of emulsions. When difficulties were encountered in obtaining satisfactory emulsifiers during the early rush period of synthetic development, the eastern laboratory was among those called upon for a scientific attack upon the barrier. Working with others on the problem, the Philadelphia scientists aided the perfection of a method that has been utilizing millions of pounds of tallow fat in the rubber process.

Among the investigations proceeding at the laboratories is the dehydration of vegetable leaf wastes for poultry or stock food. The extensive nearby production of peas, beans, broccoli, spinach and similar crops for canning and freezing leaves large tonnages of such wastes. Potato starch, vegetable stabilizers for lard, and milk by-products are among other fields of inquiry.

VIII

As stated in an earlier chapter, no American crop is more deeply entangled in difficulties than cotton. When the Southern Regional Research Laboratory was assigned to work on peanuts, sweet potatoes and cotton, its directors had no reason to complain because longer lists of products had been assigned to each of the three other laboratories. Cotton was challenge enough.

War stepped domestic consumption of cotton up from the peace-time 1935-39 average of about six and one-half million bales to eleven million bales. That logically led cotton people to ask why the country could not regularly consume, say, ten million bales. That, as R. J. Cheatham of the Southern Laboratory told the 1944 Cotton Research Congress, would be about 37 pounds for each American man, woman and child as compared with about 25 pounds each before the war. The increase of 12 pounds of cotton per person, he said, "would be just about enough to supply each of us with, say, two extra sheets, an extra tire, an extra pair of overalls, and three extra shirts or dresses, or equivalent products."

Fibers find such an extraordinary number of uses that a great variety of attacks must be made to find new uses for cotton and to insure its hold on old uses. Competitive materials, notably rayon and paper, are forever offering to take over cotton's work.

Who has not been made self-conscious at one time or another by a squeaking shoe? That was one little problem that found its way into the southern laboratory. It seems that sometimes a squeak resulted when the thread with which the shoe was sewed stretched and became loose. A method was worked out for making yarn that stretches very little, which resulted in a thread that, when used in shoes, takes a good bit of the squeak out of footwear.

Fish nets, lines and other fishing gear consume 10 million pounds of cotton a year, and microorganisms consume or damage the cotton in them. A resinous preservative material was found which may help to hold the fisherman in line as a cotton consumer.

The United States post offices have long been steady patrons of the Indian jute producers. They use a carload a week of jute twine for tying bundles of letters. Postal workers prefer it to cotton for two reasons. Jute is easier to break without cutting their fingers. Jute would not stretch, as cotton did, so as to let bundles of letters fall apart. The southern laboratory worked out a twine that was pre-stretched and otherwise satisfied the postal requirements, thereby adding a home market for a carload a week of cotton instead of imported jute.

The pre-stretching method is one of several efforts by which the southern laboratory is seeking to hold cotton's place in the highly important field of automobile tire fabrics.

These are examples of the innumerable approaches in a research effort concentrated on making cotton and its products more useful. Because it involves an interesting process that is seldom described, the story of another research, this one with cottonseed oil, is given a bit more space.

When sheet steel is being coated with tin for manufacture into cans, it undergoes a carefully controlled process. Not only must extreme care be taken to obtain a uniform coating of tin, but to leave the coating so that subsequently it will not color or corrode and so that it will take lacquer and solder reliably. The thin sheets of steel are fed into a large, enclosed cast-iron pot of peculiar shape, divided into two compartments which are connected at the bottom. Through rollers, the sheets first go through a thin layer of molten zinc chloride flux. The purpose of this is to clean the black sheet surfaces thoroughly, remove all the moisture and prepare the surface so that the tin will adhere uniformly. From this the sheet moves, at the rate of from 150 to 350 inches a minute, into molten tin. From two and one-half to five tons of tin are in the lower part of the pot. On the first side the temperature of the tin may be as high as 650°F. On the other side it may be no more than 475°F. On top of the tin, on the exit side of the pot, is a deep bath of palm oil, heated to around 465°F. Terne-plating is similar, except that instead of tin alone the coating mixture is one-fifth tin and four-fifths lead.

The palm oil used in the process is a product of Nigeria, the Gold Coast and the Belgian Congo of Africa, and of the Netherlands Indies, Sumatra in particular. Palm oil probably became the preferred material simply because the British had the oil available within the empire when the tin plate process was developed in Wales. The oil is edible. The United States normally has imported upwards of 250 million pounds annually for use in foodstuffs and soap and for the plating industry.

When palm oil supplies were threatened during the first world war, the Bureau of Chemistry demonstrated that partially hydrogenated cottonseed oil might be used in the tin-plate process. As the palm oil shortage threatened again during the recent war, the southern laboratory was directed to carry the studies further. The researches proved that so far as the needs of the plating industry are concerned, the palm oil shortage can just as well be permanent. Home-grown, home-hydrogenated cottonseed oil met all the requirements and was extensively adopted for the plating industry's use.

IX

A war task of major importance fell early to the Western Region Research Laboratory. That task was to improve the dehydration of foods. It commanded the major portion of the laboratory staff's time during the war years. While perhaps neither the members of the armed forces in remote lands nor scientists toiling with the problem would claim that dehydration made foods more palatable than fresh foods, none will deny that food, dried and concentrated, was delivered where otherwise it could not have gone, and that immense quantities of shipping space were freed for other equally important uses. Technical advances were made which added largely to knowledge of the subject, and among them were a few that may be expected to find permanent peacetime applications.

Although laboring under war pressures, the western laboratory developed a food process that quickly won commercial acceptance. This is a method for utilizing the rich flavors in fruits which because of shape or size are not marketable in whole form. The result has been a new range of flavors particularly suitable for ice cream. Cantaloupes, for instance, are pulped and prepared so that not only the flavor, but also a substantial part of the fruit's food value can be imparted to the ice cream. The process is also applicable to peaches and berries.

X

Why does cork make a good liner for the inside of a crown bottle cap? At least four good reasons could be cited by a well-informed cork salesman. He would point out that cork is compressible; it "gives." Cork is resilient; take off the pressure and it will tend to resume its previous form; to a technical listener the salesman might describe this characteristic as resistance to fatigue. Even more necessary to the task of closing bottles up tight, considering the content of a good many bottles, is the requirement that the material be impermeable to gases.

After the salesman had explained all this, one might still ask why cork performs in such a manner. A physicist might have to supply him with the final answer: the structure of cork consists of an aggregation of essentially uniform, minute, hollow cells, with cell walls that are elastic and relatively thick.

When government controls were set over the entire cork supply in the midsummer of 1941, the bottling industries recognized that a dark and considerable problem might appear early in their future. Only two years' supply of cork for all purposes were in the country. Spain and Portugal and North Africa were in a poor position to send any more. And just to put that little dab of cork in the tops of one year's supply of bottle caps normally calls for 30,000 *tons* of cork.

Before long, Dr. E. C. Lathrop, the chief of the Agricultural Residues Division at the Northern Regional Research Laboratory in Peoria, was requested to think about making up something that would be as good or maybe a little better than cork and not too expensive. Dr. Lathrop is no eager-eyed youth looking for molecules to conquer. With a successful industrial career behind him, he had come to the Peoria laboratory hoping to find a few interesting things to do while enjoying the rewards of his fruitful past. But war times demand hurry, and before the cork supply was used up he and his associates—all these laboratory operations are teamwork jobs—were ready.

They were ready with Noreseal. The formula is public, in case you want to make some. You start with 100 parts of ground peanut hulls; cornstalks or sugarcane bagasse will do about as well. That is the filler. Then put in 100 parts of glue or gelatin. That is the elastomer material. For a plasticizer, the recipe calls for 75 parts of glucose or glycerine. Invert sugar, sorbitol, or some of the eastern laboratory's bland apple sirup could be used if you were out of glucose. Water, 350 parts. One or two parts of saponin or sulfonated hydrocarbon to make the mess foamy. Finally a couple of parts of formaldehyde as a settling agent. If all this has been done just right, the product will be a nice tan-colored sheet that can be stamped out into neat round fillers for bottle caps, or made into a rod just the right size to permit slicing the fillers off the end. Composition cork comes in sheets and rods, too.

Technical tests proved that Noreseal would not only do anything cork could do as a bottlecap liner, but could stand off fungus organism twice as long. Moreover, warm Noreseal could be squirted right into the bottle cap, thus eliminating an operation or two.

The cost of cork in 1944 was 4.17 cents per gross of liners. Cost of Noreseal, 2.47 cents; an estimate based on pre-war cost of the materials was 1.62 cents per gross.

Out of the Peoria laboratory has come also a new film-forming resin which promises to out-shellac shellac. Soybean and linseed oils are the basic material from which it is made. Called Norelac, the name is derived from the first letters of NOrthern, REgional, and LACquer. Heat-sealed, moisture-proof containers for such products as foods, chemicals and precision machine parts are made better by Norelac.

Known as a thermoplastic resin, the material adheres readily to glassine, kraft and sulfite papers, to aluminum and lead foil and to cellophane. Tough and durable, it serves not only to moisture-proof but to laminate. It resists water, alkali, acid, vegetable oils and even some of the organic solvents. Commercial production has been growing.

Another product is called Norepol, the last syllable being the first letters of polymer. Soybean and other vegetable oils are the raw material. Norepol is a substitute for rubber in a number of uses, such as gaskets, jar rings, insulation and rubber heels. For a time during the rubber shortage Norepol was manufactured in quantities by a Detroit chemical firm, but was discontinued because of the shortage of food oils.

The northern laboratory has made extensive investigations into straw resources, looking to their larger consumption in the container board field. Substantial advances have been made toward a process which may permit community utilization of straw, on a sort of vertical diversification basis, in local manufacture of rough building boards.

The most thoroughgoing study yet undertaken on methods and costs of turning grain into industrial alcohol for many purposes is on the program at Peoria. A large pilot plant where processes and materials can be tested on what amounts to a semi-commercial scale, has been erected.

XI

Their war services extremely well performed, the four regional research laboratories have again turned their full efforts toward the original purposes. The foregoing accounts are by no means intended to present complete records of their accomplishments. A few incidents have been chosen to illustrate the capacity of these institutions to deal with highly difficult problems and to conduct research for which previously no adequate facilities existed. Several interesting inquiries have gone without mention.

Now, as never before, the United States is provided with buildings, equipment, and scientific staffs to pursue whatever leads may promise better utilization of the nation's crop resources. Not only will the laboratories discover many new things that can be done; they will discover, and remove from controversy, some of the things that can not be done economically under present conditions. Perhaps unfortunately they are more or less limited by the wording of the law to the study of materials that are regarded as surpluses. Exceptions to this limit during the war were many, for little if anything was surplus then. For instance, an inquiry was conducted into "Jim Hill mustard," the mustard that tumbles from the Dakotas to Idaho and beyond, to see whether in its tiny seeds there might be an oil that would replace the rapeseed oil supplies shut off from Japan. Rapeseed oil possesses superior qualities for use as a marine lubricant. The mustard seed had 32.6 per cent of oil but it didn't meet the need. Nevertheless, facts about it are now known and on file. Although not a crop, certainly it is a surplus, for wheat and flax growers consider it one of their worst weeds and think that any of it is too much. One day the study should be picked up to determine whether there may not be a commercial value for some other purpose. So with large numbers of other plants which grow but are not crops, or are not surplus crops. In time, every potential value of every plant ought to be explored.

CHAPTER XX

Chemurgy Reaches the Grassroots

I

THE broad thesis that countless new industrial uses can be developed from farm-grown raw materials and that new plants can become crops is entertaining enough as an idea. Long before any fruit is borne in the way of new dollars for farmers or new products for consumers, a formidable series of detailed efforts must intervene. To talk about the theory is one thing, quite another to translate the theory into production.

What raw materials? What new crops? What new uses? Who pays the bills? Who does the work? Who will buy the product? Someone has to ask these and a hundred other questions. Someone has to answer them. To find the answer to one specific question may require thousands of dollars and thousands of hours of patient search by highly trained scientific men.

Then, the United States is a pretty big country, with mountains and prairies, plateaus and valleys; with counties where the raindrops are seldom seen and spots where six and even ten feet of rain may fall in a year; with vast reaches of high fertility and broad stretches that verge on barrenness; with areas that, being high and arid, are suitable for varieties of plants that will not grow where the land is high and humid; with these and almost every other conceivable combination of conditions, except the truly tropical, affecting plant growth. These diverse sections likewise are variably located with reference to transportation and markets, so that the economics of place affect them unequally.

Perfectly sound as a national or international concept, chemurgy can only work when the idea is applied with wisdom to a specific set of actual conditions. This was quickly and generally recognized. Men from Florida thought of tung trees and citrus by-products while men from Illinois were considering soybeans. All the impressive progress that has been achieved has taken place when some one has chosen a particular product, or a particular by-product, and has set out to find a definite economic usefulness for it and economic means to accomplish the utilization; or when some one has taken a specified area or set of conditions and set out patiently to adapt a plant of known value to the natural conditions of that area.

Without attempting a comprehensive survey of these localized undertakings it may be interesting here briefly to sketch efforts which men, imbued with chemurgic determination, have pursued in various sections of the country.

II

No one from Texas registered at the First Dearborn Conference in 1935. During the year following that meeting, regional conferences were staged at Pensacola, Florida, at Jackson, Mississippi, and Beaumont, Texas, among other cities. The significance of the chemurgic idea began to arouse a very small number of southern leaders.

By the time the second chemurgic conference was held in Detroit in 1936, two or three Texans thought it might be worthwhile to look in. One of the registrants was far-seeing Pete Lawson, who arrived to represent the Beaumont Chamber of Commerce. Pete Lawson was no Texas magnate. He was a modest ex-newspaperman employed by the Chamber.

But he knew a good bit about the vast reaches of East Texas, where rich lands and poor, pine trees and swamps had brought wealth to a few and left many in poverty. He was dreaming dreams of putting Texas soil, sun and rain to work for the benefit of Texas people. He had a few months before promoted a tung oil conference in Beaumont. Lawson could communicate his enthusiasms. To him many a Texan is indebted for a clear comprehension of chemurgic potentials, and for the urge to make personal efforts toward their realization.

Bald, bright-eyed and alert, Victor H. Schoffelmayer took a seat at the press table. Here was a Texan who missed no moment and none of the significance of the long sessions. Agricultural editor of the *Dallas News*, he painstakingly filled notebook after notebook with facts and observations from the proceedings. The notebooks he still has, filed away with hundreds of their predecessors and successors; for he is one of the few American newspapermen whose daily notes are not only preserved but are legible, to their writer at least, years afterward. Each evening Schoffelmayer filed a long dispatch for his paper. He has never since ceased to write about chemurgy. For that matter, he had written about the subject before. He had lately met Dr. Charles H. Herty and from him had caught the vision of wealth in the pine trees. Deep in his being was the impulse of the future, the inclination to envision the hopes of tomorrow and to portray them to his readers.

The big bankers, the oil barons, and most of the established business leaders viewed the rise of chemurgic interest in Texas without evident inclination to lend their time or to reach for their checkbooks. Professor Willis W. Floyd, however, started a course in chemurgy at Sam Houston State Teachers College. Shortly his students were taking castor beans, peanuts, peach seeds and other home-grown products apart and trying to put their components together in new forms for new purposes. At Denton, north of Dallas, a senior student named Gilbert C. Wilson began his course toward wealth and fame by doing new things with sweet potatoes. Citizens of the little hamlet of Romayor in the valley of the Trinity River chipped in with dollars and days to build a frame laboratory where, under the leadership of Melvin F. Handley, one of Floyd's students, the boys and girls of the neighborhood set out to explore the plant life of their region and to discover, if possible, its industrial values. Their inspiration had come by way of Pete Lawson from a unique character, a long-bearded ex-soldier of fortune named Basil M. Hatfield, who as a sort of modern Johnny Appleseed spent his last years up and down the Trinity, trying to show the people that they were living in the midst of unrealized opportunities. At Lawrence, the Luling Foundation devoted acres to tests of chemurgic crops. In the lower Rio Grande valley adventurers began laying the foundations upon which a number of solid enterprises based on chemurgic inspirations have since grown.

Schoffelmayer never ceased to write in the *Dallas News* about every phase of chemurgy that might concern Texas or inspire action. Backed wholeheartedly by his publisher, George B. Dealey, he traveled Texas, the South, and into the North and East to report the applications of science to agriculture's products and their industrialization. In December, 1944, he was elected president of the Texas Chemurgic Council. In this group for the first time the state's varied chemurgic interests were brought together.

Southern Methodist University at Dallas established an Institute of Technology and Plant Industry, with chemurgic research as its primary purpose. Dr. C. L. Lundell, the director, believes strongly that the flora of the Southwest affords a great frontier. He told the first Texas Chemurgic Conference:

> Through centuries of trial and error, our untutored ancestors discovered the uses of practically all of our economic plants of today, such as corn, cotton, cinchona, wheat, tomatoes, and onions. We have contented ourselves with the crops handed down to us through the ages, by our forbears and by indigenous races in newly conquered lands. In spite of the varied materials we now obtain from plants the potentialities of the plant world have been scarcely touched. Very little systematic exploration has been undertaken to examine the plant kingdom with the idea of exploiting products as yet unknown or unused. Areas of the earth are still botanically unexplored and thousands of species of plants still unknown to science.
>
> Even in Texas, the knowledge of our flora is fragmentary. How many plants are still to be investigated which will yield products to revolutionize our age in the same manner as rubber, quinine, vitamins, penicillin. How many plants remain to be exploited which will give us other products such as coffee, tea, linseed oil, turpentine, lacquer, varnish, perfumes, flavorings, drugs, paper, clothing, insecticides, and the multitude of plant materials which are so commonplace to all of us.

Dr. Lundell cites, to prove his point, a small evergreen tree, *Garcia nutans*, which grows along rivers in Mexico, almost adjacent to Texas. The seeds yield an oil with an iodine number of 177 "superior in important respects to the finest tung oil from Asia." While tung oil is imported extensively, and large investments have been made to establish the tung tree along the Gulf Coast, "here in our backyard, a wild American tree with a seed containing a superior, superhard, quick-drying oil has been growing unnoticed." Test plantings have been made both in Texas and in Florida to determine whether the tree can be adjusted to plantation cultivation.

Two other interesting new plants were described to the Texas Chemurgic Conference in 1944 by Dr. Lundell:

> Of equal interest is the native jojoba, *Simmondsia chinensis*, a shrub of northwestern Mexico and southern Arizona. Although its parched seeds are eaten by the Indians, and cattle forage for

the plant, the investigations of its chemurgic potentialities are only in initial stages. The seeds contain approximately 50 percent of liquid wax, currently a substitute for waxes formerly imported to make shoe polish and other products. Of even more significance are reports that this liquid has a constant viscosity over a wide range of temperatures. This is a source of vegetable lubricating oil similar to sperm oil. In yield tests as much as 14 pounds of seeds have been secured annually from a plant. The adaptability of the species is being tested at our Dallas station and in the Rio Grande Plains. In Arizona 600 acres have been planted by Durkee Famous Foods, a division of the Glidden Company.

The *chilte* tree, *Cnidoscolus elasticus*, closely related to our Southwestern *bullnettle*, is native in the interior mountains of Durango, Mexico. It was my task in the spring of 1943 to lead the exploration party sent out by the United States Government to find and evaluate this tree which reports indicated as a possible rubber source. Not only did we confirm its value as a rubber producer, but subsequent tests have revealed that the resin in its gum is of superior value as a hard surface coating, and its seeds are a source of vegetable oil. Like so many other promising species, the wild stand is limited, and its introduction into cultivation is therefore necessary. By the chewing gum industry, chilte gum is considered to be an acceptable substitute for jelutong, formerly imported from Borneo. *Chilte* seedlings, now growing in Texas alongside those of *Garcia nutans*, jojoba, and other novelties, have made remarkable growth, reaching a height up to 6 feet and a diameter up to 2 inches in eight months. *Chilte*, jojoba, and *Garcia nutans* are but three of the estimated 75,000 species native to our Southwest and Mexico. What about the possible economic value of the other 74,997?

Besides many other plant investigations afield, Dr. Lundell is directing laboratory research into the values of grain sorghums and into the oils of okra seed, cedarwood and safflower seed. "The basic wealth of Texas is Agriculture," he insists. "It is the only renewable source of wealth, the only inexhaustible source under proper management."

III

The Fourth Annual Chemurgic Conference was held in Omaha, Nebraska, in 1938. The same city had been host to a regional conference the year before. And to the first conference at Dearborn there had come, among other Nebraskans, a quiet gentleman named C. J. Claassen.

Claassen, a farm boy from the Beatrice neighborhood in Nebraska, had accumulated some years of experience as a banker. He decided that farms, properly managed, were sound business and that management could be organized. With a bank's portfolio of foreclosed farms to begin with, he established the Farmers National Company as a management organization. This has since grown to impressive proportions, managing several hundred farms in Nebraska and Iowa for both corporate and individual nonresident owners.

The theory of chemurgy appealed deeply to Claassen. Because he said he could not pronounce the word chemurgy, he refused to preside at the first conference in Omaha. However, pronounce it or not, practical applications of chemurgy for Nebraska and Iowa were much in his mind, and day by day he talked about possibilities with his neighbors. Through Claassen, and from other sources, other Nebraskans became interested. Notable among them was a farmer from Kearney, Frank Robinson, a kindly, persistent enthusiast whose efforts later accomplished much toward bringing to Omaha a large alcohol plant. Earle G. Reed, agricultural agent of the Union Pacific, enlisted as a powerful supporter. Carlisle Hodgkin, then farm editor of the *Omaha World-Herald*, reported objectively upon chemurgic developments as he saw in them significance for Nebraska.

Before long a public demand for concrete activity became evident. The unicameral legislature responded by making a modest appropriation for the establishment of The Nebraska

Chemurgy Project, to be operated from Lincoln, with the College of Agriculture as a base. Dr. Leo M. Christensen was chosen director for the project. The industrial development of plant materials has been Christensen's primary enthusiasm since, as a student of Iowa State College, he had worked with the chemists and chemical engineers of that institution. Early in the thirties he was one of an Iowa group who had made extensive studies of industrial alcohol production from grain and of anhydrous alcohol as a motor fuel ingredient.

After a survey of Nebraska soils, rainfall and other factors, along with current plant resources, Christensen chose safflower as one item in his program. Safflower is described as "a coarse, erect, glabrous annual herb which grows 12 to 36 inches in height." The seed contains upwards of thirty per cent of an oil which corresponds approximately to linseed oil for commercial uses. As with most other oilseeds, the cake is valuable for feeding livestock. Since the United States normally imports about half of the drying oils needed for paints and protective coatings, obviously a market awaits a satisfactory output. And since safflower appears to prefer locations of more than three thousand feet elevation where the sun is bright and moisture slight during the ripening period, it might become an alternative to wheat if once proved to be a profitable crop.

Before the war safflower had been produced on a commercial scale for a year or so in southeastern New Mexico, but had been abandoned upon the government demand for other crops from that section. The safflower pioneer of the country is Alfred Rehbien, a Montana farmer who has grown crops of it for several years and who has vigorously proclaimed his faith in its value. Rehbien obtained seed of strains from Russia and India, where the plant is cultivated for local uses, and by selection had improved the yields. Frank Rabak, of the U.S. Department of Agriculture, had begun a small research program on the culture of safflower as early as 1922, and by distributing seed had persuaded several state experiment stations to make investigations.

Christensen obtained seed of twenty different varieties. Tests in all parts of Nebraska established within three years that two of the Hindu varieties were superior to any of the Russian seed and the most promising for further development. Yields of seed have averaged from around five hundred pounds per acre to more than a ton, with a gross per acre value of oil ranging from about twenty-five to more than one hundred dollars at current prices. A small and rather tentative commercial production was undertaken in 1945.

However, a new undertaking of this character never gets under way smoothly. Among the several safflower problems encountered is its tendency to remain rather long in the "rosette" stage during which weeds may gain the advantage. This is being attacked by selecting and breeding strains which do not have that tendency.

Research into the chemical nature of safflower oil has become active with the prospect of supplies of the seed. This may develop a specialized demand, should the oil prove to be peculiarly fitted for uses not so well met by other oils. As a carefully worded bulletin on its culture issued by the Nebraska Experiment Station says, whether safflower will become a profitable crop "probably will be determined within the next few years."

The Nebraska Chemurgy Project has been looking into several other new crop prospects, and in some instances has worked on engineering as well as agronomic aspects. For castor beans, which have yielded in the state as much as 1842 pounds per acre, attempts have been made to obtain high-yielding varieties, ripening early enough to assure maturity, with growth characteristics that fit the plant to be reaped with the economical combine-harvester. More than 500 strains of castor bean seeds have been grown in the search for the kind that may be most desirable.

Sesame seed, which bakers buy to flavor rolls and breads, has yielded 600 to 800 pounds per acre, which at the recent price of 14 cents a pound promises an excellent return. Except for the necessity of hand-thinning, the crop can be handled with machinery. Christensen has been looking into the application of a new idea which was first developed to avoid hand-thinning of sugar beets. Beet seed grows in clusters. Californians worked out a method by which the clusters were cut into segments so that the seeds could be distributed more thinly in planting. However, no exact spacing could be obtained. Dow Chemical Company men then evolved a process for pelleting the seed. Each small seed is enclosed in a pellet, and all the pellets are uniform in size, so that planting machines can drop them equidistant in rows. The laborious, bending task of hand-thinning can thus be avoided. Results have been good in certain areas, less satisfactory in others. For good measure, the pelleting material includes a disinfectant to destroy fungus, a hormone to stimulate growth of the sprout, and fertilizer to give the young plant a fast start. Success in planting depends somewhat upon moisture conditions that dissolve the pellets promptly and uniformly. Christensen hopes this idea may permit sesame seed production to escape the hand-thinning cost.

Coriander, henbane, a drug plant for neuralgic and lung conditions, and pyrethrum, an insecticide plant, are being investigated. So also is hemp.

One failure reported by Christensen was an attempt to extract such oils as safflower by fermentation instead of by pressure or solvents. Several bacterial cultures extracted oil but obtained hardly two-thirds of the total content. That was not good enough, so the experiment was set aside, as many others in chemurgy will have to be until new ideas appear which suggest further effort.

Foremost in Nebraska interest naturally has been the large grain alcohol plant at Omaha.

IV

Chemurgy came to Idaho by the public utility route. C. J. Strike, president, and Ralph E. Gale, general sales manager, of the Idaho Power Company had become indoctrinated with the idea that the agricultural resources of the Gem of the Mountain state could be made more productive through new crops and new uses.

Gale talked chemurgy to farmers' meetings and found them interested. The first tentative undertaking was to distribute for test plantings seeds of a half dozen or more oil and drug plants. From the farmers Gale heard repeatedly a question: What can we do with our cull potatoes? Idaho, of course, claims that in order to protect the high reputation of its best it throws away potatoes that would be pretty good elsewhere. At any rate, the quantity of noncommercial grades is usually five to six million bushels out of the annual crop of thirty to forty-four million bushels.

The obvious answer to that question was potato starch, and the obvious action was to build some plants in suitable locations. A war was on and markets were certain. Supplies were not certain. Steel for girders could not be furnished, the steel mills said, and electrical firms had no equipment to sell, and the War Production Board had no priorities for potato mills.

An abandoned bridge had girders. These were welded into supports for the drying drums and spinners of the starch plants. Old automobile transmissions were doctored up to serve as gear reduction units to run agitators in settling vats.

Rewound electric motors were put to work. Equipment was trucked in from an abandoned beet sugar factory.

More than $2,250,000 worth of starch was produced during the first four seasons of operation. Considerably more than 350,000,000 pounds of cull potatoes were profitably utilized. The four factories, located at St. Anthony, Twin Falls, Blackfoot and Menan, are owned by local people and each is well managed. From 25 cents to 27½ cents per hundred pounds of culls, as they come, is the base price at the plant for the raw material. The return to farmers varies with the cost of transportation, most of which is over distances less than twenty-five miles.

Two of the plants provide for a capacity of ten tons daily. They required an investment of about $62,000 each. One plant has been enlarged to fifteen-tons capacity to take care of wet starch delivered from the fourth of the plants; a smaller one is of five-tons capacity, costing about $35,000 to build and equip.

This Idaho effort has been a success because the sponsors approached the whole undertaking along sound lines. They had the potatoes. For the immediate war period they could be sure of markets. Before starting to build, they asked the National Farm Chemurgic Council for a comprehensive report on starch-factory procedure and economics. This they followed with competent personal investigations. They consulted with experts. Finally they arranged with a firm well established in the starch field to buy and distribute their product.

Production of white potato starch is by no means a new industry. Back in 1860, before corn starch became a formidable competitor, 152 factories were listed in the U.S. Census. Aroostook County, Maine, in 1940 had twenty-seven of the twenty-nine plants still remaining, with a yearly capacity of 25,000,000 pounds of starch.

Textile plants are the largest users of potato starch. The product goes also into paper, adhesives and food products. Stein-Hall and Company, which markets the Idaho production, supports research looking to wider outlets.

Profit from the factory operation depends more upon the percentage of starch recovered than upon any other one thing. The Idaho Experiment Station (Bulletin 259[a]) sums the matter up:

> The Idaho cull potato will contain from 14 to 16 per cent starch. If all the starch could be recovered, the yield would be from 16.5 to 18.5 pounds of starch at 18 per cent moisture for each 100 pounds of potatoes processed. The actual yield obtained in the plant varies from 11 to 15.5 pounds of starch for each 100 pounds of potatoes received. When it is considered that a pound of finished starch is worth $0.0485, the importance of recovery can be appreciated.

The mere manufacture of starch does not exhaust the possibilities of the cull potatoes. Values remain unutilized in the wastes of the process. The Idaho Bulletin comments on the by-product future:

> Analyses of the waste materials show that the starch plants have a high percentage of soluble proteins while the materials from the dehydration plants carry a high percentage of starch, some of which have been gelatinized or converted to sugar. Three possible uses are suggested for these materials:
>
> 1. The solubles be reconverted in their present form for starch feed or fertilizer;
> 2. The material be used for producing high protein feed yeast;
> 3. The material be used for industrial alcohol fermentation.
>
> Under the present practices of starch production and potato dehydration in Idaho, the waste products are estimated to equal the loss formerly attributed to the non-use of cull potatoes. Although the cull problem has been eliminated as far as the potato growers are concerned, it remains a serious problem for the starch producer and the dehydration plants.

Progress is never final! Each accomplishment, each new fact, branches inevitably into new problems and new questions, each one of which may turn out to be a new opportunity.

V

The necessity that compels chemurgic effort to subdivide to adapt to local conditions is illustrated in the state of Washington. The Washington State Farm Chemurgic Committee began holding statewide conferences. The gulf between the interests of the fruit men in the orchard districts, the forestry concerns of the wooded areas, and the diversified activities of other sections proved a barrier to effective, down-to-earth procedure. Regional sessions, built around the activities centered at such points as Olympia, Bellingham and Spokane, proved to be more productive.

An energetic group of Washington farmers led by Henry P. Carstensen, master of the state Grange, acquired rights to a process for manufacturing glucose. Cull potatoes and low-grade wheat are among their raw materials. Establishing plants at Wenatchee and Lynden, they built up a flourishing wartime business with high hopes for its permanent future as an outlet for wastes and surpluses.

A solid background for the Washington chemurgic program is provided by a legislative appropriation of $150,000 "for research in connection with furthering the development of industry and agriculture within the State of Washington."

Cecil C. Clark of Yakima County, reporting to a conference in Spokane near the close of 1943, used language which well typifies the soundly realistic attitude with which farmers venture into new crops. After mentioning that in 1942 he had produced about ten acres of sage, he went on to say:

> We expanded this sage to about 17½ acres this year and found that on the planting of a year ago we produced something

> like 3½ tons of dry sage per acre, which is a phenomenal record compared with anything else we know of in sage-growing. But it should be borne in mind that it costs us three or four times as much per pound to produce sage as it did to import it from Dalmatia before the war.
>
> During the past two years we have grown small commercial lots of henbane, belladonna, stramonium, wormwood, rue, marjoram, thyme, and poppy seed. We have had less than commercial samples of sweet basil, coriander, tarragon, tobacco and a number of other herbs. All of these plants seemed to do fairly well from a production standpoint. But even though offered at one-half market quotations, we will have most of these on hand.
>
> Of this list, there are perhaps two that would be good crops and for which there seems to be a good demand. Poppy seed would be very profitable and, I believe, would make a permanent crop if it were not for the new Narcotic Act which was passed a year ago this summer and eliminates the growth of all poppies. Marjoram seems to be in fair demand and we may plant some more next year. We also grew a little over an acre of paprika and netted several hundred dollars for one acre. Paprika of the right strains no doubt could be grown profitably.

One wonders whether Mr. Clark had the right strain of paprika!

Washington's chemurgic leader, Dr. H. K. Benson of the University of Washington, has consistently taken a broad view of the field in his state. He has thought not only in terms of new crops and new uses for the crops now grown but has as well realized the importance of finding means for more intensive realization from the forest wealth of the state. Recovery of alcohol from sulfite waste liquors, production of cork materials from Douglas fir bark, tannin from hemlock bark accumulations, and other utilizations of lumber wastes have been pursued.

VI

A public utility, conscious of the state's need for solidly-based new agricultural industries and a more permanent population, has led in fostering chemurgy in Oregon. H. W. Derry, manager of the new industries department of the Pacific Power and Light Company, has been the guiding influence in building up the Oregon State Farm Chemurgic Committee. Special committees have been set up to examine opportunities in flax, new crops, wastes from nuts, canneries and other packing operations. Forestry products in Oregon, as in Washington, are an important chemurgic concern.

Derry once pointed his finger at a reason which, though seldom expressed, has interested many men in chemurgy. In an address to the Oregon committee he said:

> One of our great problems in Oregon is that we are mining one of our best natural resources. That is our young men and women.
>
> Our boys and girls are educated through the primary and grammar school system. The more fortunate receive a high school education. From these the pick of the crop are sent to college for further training. It costs the people of the state and especially the parents a great deal of money to give this education to our children but it happens that during the senior year of the college education representatives from large industrial concerns in the East call at the colleges and solicit the highest ranking, best qualified students to accept positions with these industrial concerns in the East. They offer salaries which are much higher than can be obtained through our present organizations in Oregon. They also offer a continuance of their education system whereby they will be paid during this process. The result is that the young men and women feel that they have to accept these offers as there is no similar plan whereby they can remain in Oregon where they would like to stay. They do not want to leave the country in which they are brought up and which they love but unfortunately we have not yet built up our industrial organization to the point where we can offer them jobs of a comparable nature.

Raw material or original production enterprise still prevails in the Northwest, as in many parts of the nation. As Derry indicated, these areas do not present to youth certain kinds of opportunities which more industrialized sections offer. Chemurgy, as a route toward larger diversification of business activity, holds promise of developing types of economy in which a larger percentage of the bright youth can see satisfactory opportunities.

VII

California chose a different approach. Albert M. Paul, president of the California Products Company and a member of the board of governors of the National Farm Chemurgic Council, once explained why.

"Many duplicate demands," he pointed out, "are made upon executives who are willing to devote large portions of their time to constructive projects. These men inevitably gravitate to positions of leadership and each new movement places one more demand upon them."

Consequently, in order, as Paul explained, "to get things actually done," California leaders chose to make their chemurgic program an integral part of their established state-wide Chamber of Commerce. A chemurgic, or by-products committee within the Chamber is charged with acting, as the state council committees operate elsewhere. They have the advantage of a staff already available and of ready communication with representatives of all the coordinated agricultural and business interests of the state.

Californians have long been prompt to investigate commercial prospects of new crops, and have eagerly followed through with tests of the adaptation to their conditions of various items suggested by the Chemurgic Council. Located far from the nation's more populous markets, they have also long been alert to the advantages of research in order to make the most of their resources. The citrus and walnut cooperatives have as a result of their own researches utilized by-products to the substantial profit of their grower-members.

The Western Regional Research Laboratory was hailed as a boon by the agricultural groups of the state. Their representatives work closely with the laboratory. Al Paul's own industry is an example. One of his products is cream of tartar, processed from the lees of the wineries. "No longer is the California vintner discarding the lees from his wine tanks; every pound is being preserved," says Paul. "Processes heretofore employed for recovering tartrates have been recognized as wasteful. Dr. T. L. Swenson of the Western Research Laboratory assures me of their willingness to cooperate toward an ultimate 100% recovery."

If even the lees of the wine tanks are worth saving, so, too, Californians believe, are the 200,000 tons of such materials as waste stalks from asparagus, celery and artichoke trimmings. The laboratory has developed a process for using these fibrous substances as a matrix in which are embedded such other wastes as almond shells and rice hulls. The product is a fiber board.

VIII

The Indiana legislature has provided an appropriation of $35,000 a year for chemurgic research in subjects of particular promise to the Hoosier state. Purdue University has been charged with handling the research through the agricultural college there.

A Maryland Farm Chemurgic Committee was organized in 1945, after extensive preliminary surveys of the need for such a body. With agriculture, industries, and the state university tied together, plans for applying the chemurgic philosophy to Maryland resources are the objectives of the group.

In the summer of 1944 Oklahoma held a three-day chemurgic conference which commanded perhaps the largest attendance of any meeting, national or state, ever devoted to the subject. Governor Robert Kerr presided at all the sessions.

The Oklahoma City Chamber of Commerce threw its entire energies behind the program and has put the state on the alert to overlook no opportunities which chemurgy may indicate to have promise for the state. This was not a mere outburst of momentary enthusiasm, having been preceded by smaller meetings, organization activity and quiet resource surveys over a period of several years. An equally strong conference was held in May, 1946.

A dozen other states have committees, or have approached their chemurgic objectives through established organizations. In Arkansas, for instance, the state agricultural and industrial commission, an official body financed by the legislature, is the chemurgic agency. Vermont, through the leadership of Joseph Winterbotham, has tied chemurgic exploration into the experiment station and other bodies. Illinois has a committee of individuals who are personally active on chemurgic fronts. New Mexico and Missouri set up their committees in 1946.

These are some of the approaches through which progress has been made, a little here, a big move there, and now and then a setback in another place. Research is the basic theme of chemurgy. Find the facts! No chemurgic effort succeeds unless the facts support the hopes behind it; and so many of the facts are regional and local that regional and local approaches are logical. There are many others besides the particular methods described in this chapter, as the reader who proceeds through the book will note.

CHAPTER XXI

How the Chemurgic Council Works

I

A CHEMICAL manufacturer whose business, so far as he knew, had no particular agricultural relationship, was in a Detroit hotel while the 1937 Farm Chemurgic Conference was in session. He dropped into one of the meetings, largely from curiosity, and listened to the program.

He went home with an idea. An entirely new department was set up in his research laboratory. The next year he was in the market for a million bushels of soybeans. A few years later his company was conducting what may rank among the more important of the many soybean study projects.

The conferences have proved to be a highly effective means for obtaining practical results. The programs are designed as forums for the free presentation of facts, ideas and reports of progress. They are uncensored. While reasonable caution is exerted to avoid wasting the time of listeners, men with new ideas are encouraged to expose them. Occasional crackpots have been heard, but experience in program building has taught some foresight in recognizing the species. No one is wise enough to be sure in advance that what sounds like a crackpot dream will not prove to be true vision, and one of the purposes of the conference is to challenge new thinking. Nevertheless, most of the program content is devoted to sound and serious discussion. Many of the papers are reported and reprinted in the scientific and industrial press.

A young man from Texas drove to one of the Chicago conferences with an idea and a flivver full of his friends. Before he left the meeting he had an order that launched him into a prosperous lifetime business. Farmers have attended or read the proceedings and have gone home to develop new sources of income from their land. Representatives of community and state organizations, such as chambers of commerce, find new ideas to expand the prosperity of their home areas. Industrial listeners likewise make acquaintances and acquire ideas which they put to constructive use. Relatively few of the profitable consequences are ever reported to the organization which stages the conferences and which, after all, is operated to accomplish results rather than to compile reports.

The value of talk as a fertilizer of action has been thoughtlessly disparaged. When a manufacturer or a scientist, his mind already well stored with facts and questions about a subject, sits down in a room with a considerable number of other men, while all concentrate upon the speaker's topic, an effect can be produced. The speaker, dull, prosy and droning, as too often he is, mentions a fact or a result. Automatically the minds of a hundred listeners pick up the fact and either drop it as of no interest or value to them, or array it in line with the store already present in their minds. Occasionally one will find that the new fact, added to those he has, completes a picture in his mind. He sees something that can be done which before seemed impossible; at least, he sees a new way to try. In another instance the fact may be new, one that starts in his mind a wholly fresh train of thought, at the end of which may arrive his determination to try something that, without the new fact, would never have occurred to him.

While the chemurgic conferences are open to the public, most of the attendance is of picked people, chosen to receive invitations because their activities indicate that they can likely do something to carry chemurgy forward. Before and after the program, men meet others and talk. More than once a new chemurgic step has emerged from a huddle in the corner of a foyer or after a midnight hotel-room talk.

Out from the conferences go men with new ideas which they repeat, in conversations and on platforms, to listeners elsewhere. Facts and ideas move into circulation. Somewhere one may strike in an individual a fire that stirs him to action.

When once an idea moves into the action stage, a demand for additional facts soon arises. The Council tries to respond to that demand, either with the facts, or with directions as to where they may be obtained. The conferences themselves constitute important media for the interchange of facts. The later publication of papers in the *Chemurgic Digest*, and in scientific and industrial periodicals, carries the factual material to a larger circle of minds. Frequently the authors themselves, or their companies, give additional circulation to reprints. Thus the original initiative of the Council in staging a conference for talking purposes creates impulses that radiate far and wide beyond the sound of the talk.

II

The National Farm Chemurgic Council is incorporated under the laws of Ohio and maintains its principal offices in a modest suite at 1368 North High Street, Columbus, 1. Associate membership, open to individuals at $10 per year, is held by persons in every state and more than twenty foreign countries. Contributing memberships are held principally by corporations, large and small, whose annual fee is usually in three figures. A broad base of membership is sought, rather than large amounts from a few.

All members receive the semi-monthly *Chemurgic Digest*, a modest publication of usually twelve to twenty-four pages. Its content is principally news of chemurgic advances, along with a great deal of scientific information about crops and processes for the utilization of such advances. Large numbers of special reports are prepared upon request for members; some of these are confidential, although many are available to anyone interested. Conference papers are kept in supply for distribution in reply to inquiries and, of course, a large volume of inquiry mail from the public is answered.

From an Information File Service, to which facts of chemurgic interest are added daily, six to eight thousand reports are mailed monthly, mostly in response to requests. This service seems to be highly esteemed by members.

Ernest L. Little, the managing director and secretary since 1940, has with extraordinary industry developed the techniques of providing members with useful services, accumulating and disseminating information, and steadily widening the effective influence of the Council's work. Under his direction have been created state councils and committees which are quietly but actively at work on local and regional chemurgic problems. Varied business experience in the East and Midwest has given Mr. Little a background for his work, while his exceptional energy and understanding make his efforts highly effective.

In addition to the national headquarters at Columbus, presided over by Mr. Little, an office is maintained in New York City in the Empire State Building. The address is 350 Fifth Avenue. John W. Ticknor, assistant to the president, and treasurer of the Council, is in charge of this office, from which he keeps in touch with members and conducts numerous activities looking toward extending the usefulness of the organization.

The secretary and treasurer are the only two officers of the Council who are paid and who devote their full time to the organization. Each, of course, has a staff of assistants.

The president of the Council contributes his modest efforts from his desk as editor-in-chief of *Farm Journal*, which is located at 230 West Washington Square, Philadelphia.

III

The Council by itself neither conducts nor finances actual research. Finance for research is the province of private industries, universities, foundations, and of government. The conduct of research belongs in the laboratories, where financial provision has been made for the necessary scientific men, equipment and administration.

However, the impulse to seek new facts about the materials and laws of nature does not arise by spontaneous combustion. Research is a tedious and often expensive undertaking into which men do not launch without strong incentive. Until the last few years, the last few centuries at most, scientific research did not exist. Man got along without it. He got along badly but was not aware that with more knowledge his living could be much improved.

The Council's primary task has been to stimulate research, and then to aid in its prosecution and in application of its results.

The Council refrains strictly from any flavor of lobbying. It has no office in Washington and its representatives are not seen around legislatures. More than a dozen states have established appropriations, in one form or another, for chemurgic surveys and research. Every one of these has been the result of demand from citizens and conviction of state officials. The Council was widely credited with having inspired the four million dollar annual federal appropriation with which the four regional laboratories of the Department of Agriculture were built and are operated. The fact is that the idea for these laboratories was developed independently. The demand for them, it may be hoped, had been stimulated by the appreciation of research in chemurgic directions which the Council has fostered. Other than to supply information requested by congressional supporters of the proposal, the Council took no part. It was enough to have created the background of understanding.

As the facilities of the Council increase, broader plans for the information of the public generally will be put into effect. More extensive presentation of chemurgy by speakers and publications, by material made available to radio and press and schools, is contemplated.

IV

Holding to the idea that science knows no national boundaries, the Council has freely encouraged the application of chemurgic principles in other countries. The international interest in chemurgy was dramatized at the Tenth Annual Conference, held in St. Louis, where on one program speakers appeared from Canada, Cuba, Uruguay, Brazil, India, and China.

Canada, Argentina and the Dominican Republic have established their own national farm chemurgic councils, inspired by but wholly independent of the American organization.

While the Council is without funds and facilities large enough to send representatives or carry on active work in other countries, foreign membership is welcomed. Whenever leaders in any country choose to express a desire for assistance or guidance toward developing their own organization, everything available in the way of information or experience is placed at their service. Each applies the material as it may best fit the pattern desired abroad.

The Canadian Council works closely with the Dominion Chamber of Commerce. At its head is Mr. D. G. MacKenzie, a Canadian distinguished in the agricultural and business affairs of that neighbor nation.

Representative of foreign interest in chemurgy were the words of Dr. Lu Cheng Hao at St. Louis, when he addressed the Tenth Annual Chemurgic Conference:

> With nearly eighty per cent of her population consisting of farmers, China is primarily an agricultural country. The economic reconstruction of China will depend largely upon an agricultural reform. . . . Agricultural products will supply a large part of the raw material for China's newly developed industries . . .
>
> We find the answer in chemurgy. Chemurgy, that branch of applied science which deals with the industrial use of farm products is the most promising and practical answer to China's economic reconstruction. After the war the world will see the materialization of many large-scale chemurgic enterprises in China . . .
>
> The abundant gifts of nature can supply enough of everything for humanity if we know the ways and means to utilize all our natural resources. Basically speaking, solar energy, air, rainfall and soil are the most valuable and the only inexhaustible resources of nature.
>
> It is up to the scientists, the agriculturalists, industrialists, and particularly us, the chemurgists, to study and practice the fuller utilization of the wealth of nature, and to create more things for the better living of all mankind.

V

An exciting aspect of the Farm Chemurgic Council's experience has been the eagerness with which youthful Americans have seized upon the hopes which chemurgy raises, and upon the confidence it seems to inspire in the nation's future.

A speaker who addressed a large dinner audience in a southwestern state still gets a lump in his throat when he tells of an incident that followed the occasion. He had described, as simply as he could in a forty-five minute talk, a few of the nation's achievements in the spirit of chemurgy, and had tried to indicate without overstatement the possibilities inherent in full exploration of agricultural resources. Among those who came up afterward were a young ranchman and his wife, hand in hand, who introduced themselves and then said slowly and with an emphasis that suggested their earnestness: "Mr. Blank, your story has given us more real hope for America than anything we have heard down here in years."

Apparently they had been overwhelmed by the defeatist propaganda about this nation!—having grown so mature and old as to foreclose opportunity!

VI

The program of a national conference in Chicago in the early forties ventured an experiment. Usually the annual national conference begins with a luncheon on Wednesday and closes at the end of the Friday afternoon session. It was decided to stage an extra Friday evening session especially for the science students in the colleges and high schools of the Chicago area. The features on the program were to be addresses by M. F. Taggart, by W. E. Bigelow on developments in plastics, and an address by L. F. Livingston, of the Du Pont Company on "New Products of Chemistry." No one had an idea whether or not an audience would be present. But by the appointed time the large rooms provided by the Drake Hotel were jammed until the conference officials and speakers did well to make their way to the platform. More than 1800 students, boys and girls, had come. Both men on the program were skilled and experienced speakers and each accompanied his remarks by an abundance of exhibits of the materials about which he was speaking. The entire 1800 youngsters remained to hear the last word and many to ask questions. There remained no doubt about their interest in their futures and in the future of their country.

The Future Farmers of America is an organization of 200,000 boys who are students in the vocational agricultural high schools of the nation. Among their organization activities is a national public speaking contest. This annual contest begins on a state level. State winners compete in regional contests. Finally, at Kansas City, where the annual convention is held each year in connection with the the American Royal Livestock Show, the regional winners compete for the national championship. Speeches on chemurgy have twice won the national contest, and in many instances chemurgy has shown itself to be a favorite topic of the boys contesting.

All these experiences have combined to convince the officers and governors that for the future the Council owes much more attention to youth than has been possible to give in the formative years of the organization. The plans which have been made to this end will not be discussed here since these pages are devoted rather to what has been done than to what may yet be done.

VII

The National Farm Chemurgic Council, to sum up, is an organization of farmers and agricultural people, of industrialists and scientists and citizens. 'To advance the industrial use of American farm products through applied science' has always appeared on letterheads and literature as the primary objective of the Council. Its emblem is a lighted torch surrounded by a triangle the three equal sides of which are labelled agriculture, industry and science.

The objective is broadly interpreted. As an American organization, the work naturally centers upon advancing the use of the farm products of this country. The character of science, however, and the concept of chemurgy itself, are both too broad to restrict the philosophy to the boundaries of a single nation. Moreover, from the point of view of practical extension of the objective, the well-being of the United States is advanced as other nations place themselves on a firmer footing. The ideas of chemurgy can help them.

Some may ask whether the mere development of industrial uses for farm products is not a rather narrow base upon which to hope for broad results in terms of national and general human well-being.

About one-fourth—somewhat less in consequence of the late war's changes—of Americans live on the land. Most of them derive most of their incomes from farming.

Another one-fourth of Americans live in the villages and small towns or are so engaged that their entire incomes are received only as farmers bring new wealth, or the dollars obtained from new wealth, into town. These are the dealers in farm commodities, the merchants and bankers, the professional and service workers, all the people whose lives are supported by the agricultural economy.

When farm prices are depressed below the real values of products, as has happened repeatedly when such commodities as wheat and cotton are produced in quantities exceeding the effective demand, the incomes of both these one-fourths—that is to say of one-half—of all Americans are seriously reduced. When this occurs, the market for the industrial goods and for the services of the urban half of the nation is definitely curtailed and the makings of a depression appear.

Farmers can probably produce more food than people will buy at economically-fair prices. But there is no limit to the demands of the human race for other commodities than food.

Science can constantly find new ways to utilize the raw materials of agriculture. For years it has been doing just this. Out of the agricultural abundance of starch, oils, cellulose and proteins unquestionably more new and useful products can be evolved by research.

So, new uses are possible. As they are developed—new, non-food uses—the danger of surpluses grows less. As new crops are established, surpluses can be prevented because the new crops will have to crowd some of the old surplus-making crops out of the existing acreages. There is practically no new land. The profitable utilization of agricultural waste materials, too, will help to sustain a sound economy.

Chemurgy, therefore, is not a narrow concept. It builds broadly and solidly at the very base of the economic pyramid. Chemurgic developments result not only in new income to farmers; they add to the total tonnage of materials which have to be handled and therefore create new jobs in transportation and processing, in offices and in sales. Soybeans and cigarette paper have added to the total of American employment just as have radio and airplanes, by making jobs which did not exist before.

The work of the Council is to stimulate others to accomplish more of the same.

VIII

The basic policies of the National Farm Chemurgic Council are so definite that few other matters of policy arise to be determined. The program for the execution of these policies is, however, directed and reviewed at meetings of the Board of Governors, usually twice yearly. The members of the board are chosen either at a membership meeting during the annual conference or by the Board itself. Pains are taken to maintain a balanced representation of agriculture, industry and science. The board elects the officers.

The present membership of the Board of Governors includes thirty-one men. The members representing agriculture are:

H. E. Babcock, who operates his home farm in Tompkins County, New York, and a ranch in New Mexico. Mr. Babcock was for a long time chairman of the board of trustees of

Cornell University, and is a former president of the National Council of Farmer Cooperatives. Under his leadership the famous G.L.F. farm cooperative in New York was built up.

Cornelius J. Claassen, president of the Farmers National Company of Omaha. Mr. Claassen's company operates 1300 farms, (more than 300,000 acres) mostly in Iowa and Nebraska, for other owners.

D. Howard Doane, chairman of the Doane Agricultural Service at St. Louis. This organization operates large numbers of farms and plantations from Minnesota to Mississippi. Mr. Doane is founder of the American Society of Farm Managers.

G. G. *McIlroy*, president of Farm Management, Inc., Irwin, Ohio. Former president of the American Soybean Association, Mr. McIlroy runs his extensive home farm and his organization superintends a large group of farms in central Ohio.

Wheeler McMillen, editor-in-chief of *Farm Journal* and president of the National Farm Chemurgic Council, Inc.

Elmer Nall, farmer in central Wisconsin and a Chicago business man.

Eugene M. Poirot, farmer and livestock man, whose large farm is one of the best known in southwestern Missouri. Mr. Poirot is particularly interested in soil problems.

Victor H. Schoffelmayer, agricultural editor of the *Dallas News* and president of the Texas Chemurgic Council.

Louis J. Taber, long master of the National Grange, now president of the Farmers and Traders Life Insurance Company, Syracuse, N. Y., and a farmer at Barnesville, Ohio.

Dr. John A. Widstoe, of Salt Lake City, a member of the Council of Twelve Apostles, Latter Day Saints Church. Dr. Widstoe was formerly director of the Utah Experiment Station, president of the Utah College of Agriculture and later of the University of Utah.

Arnold P. Yerkes, head of the new agricultural development department of the International Harvester Company, Chicago. Mr. Yerkes is a former president of the American Society of Agricultural Engineers.

The members of the Board of Governors who represent industry are:

Edward J. Dies, Washington, chairman of the Board of the National Soybean Processors Association.

Howard R. Huston, New York, assistant to the president of the American Cyanamid Company.

J. F. Jackson, Savannah, retired agricultural agent of the Central of Georgia railroad.

Henry L. Kellogg, Chicago, director of the Illinois State Planning Commission.

Charles F. Kettering, Detroit, vice-president of General Motors Corporation and world-famous industrial research leader.

L. F. Livingston, Wilmington, Del., head of the agricultural public relations division of E. I. Du Pont de Nemours Company. Mr. Livingston also is a former president of the American Society of Agricultural Engineers.

Albert M. Paul, Fresno, Cal., president of the California Products Corporation.

Clinton T. Revere, New York, noted cotton expert and economist with Laird, Bissell & Meeds.

Harry H. Straus, Ecusta, N. C., president, Ecusta Paper Corporation and a pioneer cigarette paper manufacturer.

M. F. Taggart, South Bend, Ind., chief of research department, O'Brien Paint and Varnish Company.

Robert E. Wood, Chicago, chairman of the board, Sears Roebuck & Company.

The members representing science are:

Dr. Roger Adams, Urbana, Ill., head of the department of chemistry of the University of Illinois, and a former president of the American Chemical Society.

Dr. Henry K. Benson, Seattle, Wash., head of the department of industrial chemistry and chemical engineering, University of Washington.

Dr. W. L. Burlison, Urbana, Ill., head of the department of agronomy of the University of Illinois, and a former president of the American Society of Agronomy.

Dr. Karl T. Compton, Cambridge, Mass., world-famous physicist and president of the Massachusetts Institute of Technology.

Dr. George L. Cross, Norman, Okla., president of the University of Oklahoma.

Dr. Perrin H. Long, Baltimore, Md., professor of preventive medicine at Johns Hopkins University, Colonel in U. S. Army Medical Corps. Dr. Long was the American pioneer in sulfa-drug research.

Dr. Robert A. Millikan, Pasadena, Cal., chairman of the executive council, California Institute of Technology. Dr. Millikan was awarded the Nobel Prize in physics in 1923.

Dr. Charles A. Thomas, St. Louis, Mo., director of research and vice-president, Monsanto Chemical Company.

Dr. Edward R. Weidlein, Pittsburgh, Pa., director of the Mellon Institute and a former president of the American Institute of Chemical Engineers.

The number of Americans of distinguished eminence in this group not only makes it a board of notable character but testifies to the broad background of those interested in the chemurgic program.

CHAPTER XXII

What Makes It Pay? The Economics of Chemurgy

I

NO new crop becomes established and no new use is made of a farm material unless it pays. No one will make a business of growing a crop that can not be sold to advantage. No manufacturer will buy and process a farm product unless the operation will earn money. The entrepreneur may be willing to invest money over a period of years, if the stake is promising enough, before profits are harvested; if his confidence is sufficient, he may be willing to face uncertainty as to the outcome, but eventually the continuance of his effort will be determined by whether or not it pays.

In laboratory records repose thousands of notes which indicate that from a plant material products of value can be derived by given chemical and physical processes. Nothing comes of such notes until evidence also indicates that the price the public will likely pay for the product will be enough to pay for the material and for the processing with a margin for profit. The outcome does not necessarily have to be a sure thing to induce some one to expend substantial effort in its pursuit; the outlines of its probability, however, must be visibly fair.

The formula for net income in practical economics can be stated simply. *Price times quantity minus cost equals net income.* Price must be high enough, cost low enough, and quantity great enough to produce a plus result. This does not mean that a high price is necessary. A low price may move into consumption a quantity so much larger that, as long as the costs are low enough, the net income will be far greater than would result from a higher price and a lesser quantity. A five per cent profit on a volume of one hundred units produces more net income than twenty per cent on twenty units.

No effort in the field of chemurgy can be exempt from these simple facts of economic life. A new crop, or a new use, must yield a product cheaply enough to be sold at a price which people will be willing to pay for it and leave a margin of profit for those who expend effort in the growing and processing.

However, no one should conclude that because this is true it also follows that a chemurgic effort is not justified merely because it does not pay on the basis of present known facts. Facts are changeable, either by the course of events or by the advance of knowledge; their bases may be altered by changes in national policy or in human needs.

The castor bean, as an example, does not yet assure American farmers of enough profit to persuade them to adopt it as a crop. That is a present fact. Any one of several developments might alter the facts which determine the present unfavorable status.

New needs for castor oil might arise from a new industrial discovery, so that a larger supply would be required than could be imported.

National policy might be changed to provide a tariff duty or incentive payment that would stabilize or increase the price.

Improvements in the strain of castor plants might make them more economical to cultivate and harvest, and thus reduce the outlay for production.

A marked economy in the mechanical operations might substantially lower the cost of their production. Such an event might be comparable to the discovery that the combine-harvester for soybeans could replace the binder, the threshing machine, two hand operations, shocking and loading, and the labor of hauling to the stationary threshing machine. Acreage expanded swiftly after production costs were thus notably lowered.

Those who have constructive faith in the American ways of getting things done entertain full respect for facts, but they also remember that unfavorable facts have been altered into favorable facts so frequently as to justify the belief that similar things can be done again. They hold to no blind faith in accomplishment of the impossible, but they know from experience that what was impossible last year has regularly become commonplace by next year. Nothing was once more impossible than to fly two hundred miles an hour in a heavier-than-air machine, to talk overseas without or even with wires, to cure fevers with mold, or to blow up civilization with atomic energy. Nor is it necessary to fail to recognize evident impossibilities. If a bushel of corn contains only so many pounds of starch, that is all the starch or starch derivatives any one will ever obtain from a bushel of corn until more starch is bred into the corn. The size of a bushel might be increased, but that still would not make more corn. Money can be inflated, but corn refuses to respond to mere governmental power.

The proponents of chemurgy have from no source met with more criticism than from those who fail to realize that effort can alter conditions, and create new facts. I quote a typical expression:

> Unfortunately, some enthusiasts tend to burn out the brake bands on their imagination on the subject of farm chemurgy. 'Imagineering' has an important place but let us be hard headed and not count chickens before the eggs are laid. Progress, no doubt, will be made but it is safe not to bank on miracles taking

place overnight. The use of farm products as industrial raw materials must represent good economy before it makes a market. Such uses must afford a price which will be attractive to farmers. Moreover, these developments work two ways. Some of them provide new competition rather than new markets for farmers.

This mentally-recumbent position reflects the attitude of the negative, noncreative, nonhopeful observer who is habitually nonactive, nonaggressive and nonconstructive. The criticism assumes that chemurgists are not hardheaded; that they are counting unhatched chicks before the eggs are laid; that they are banking on miracles and banking on them happening overnight; that they believe in bad economy; that they do not believe or understand that producers must have attractive prices; that they think all new uses will necessarily be noncompetitive with existing markets.

Contrary to these assumptions, chemurgy owes its progress almost entirely to the fact that hardheaded, hard-working men have avoided all these mistaken views. They were men who, instead of lackadaisically saying "Progress, no doubt, will be made, but . . .," have gone out and actively helped to make it, and have done their work soundly. India and China are triumphs of the "no-doubt-but-ers." America is the land of the "imagineers."

A debt is owed by chemurgy to some of its critics. They have stimulated the elimination of errors. They have helped to harden the program into realities, so that less energy has been wasted on false leads. Neither chemurgy nor any other useful effort is much in debt to the carpers.

The emphasis which has been placed here upon low costs as a factor in successful chemurgic enterprise can be misleading, as similar unqualified statements may easily be. Obviously a farm raw material must be low enough in price that the manufacturer who processes it can figure a profit from his sales. That it has to be so low that farmers will not also make a profit in production does not follow. The present economics of alcohol manufacture and of competitive materials appear to indicate that motor fuels may not in the early future be made profitably out of corn, if the corn is to bring a price that farmers can afford to accept. As long as such is the case, if it is, motor fuel from corn appears impractical. If the alcohol demand for all chemical purposes should so exceed the capacity of cheaper raw materials to yield sufficient quantities, the alcohol maker would inevitably pay more for corn. Or, a condition might develop which, to enlarge the raw material supply, would permit farmers to grow more profitably some crop less valuable than corn but more abundant in tonnage yield per acre; a crop such as Jerusalem artichokes. Utilization of cotton in chemurgic manufacture is hindered when artificial prices are maintained by political rather than economic forces. They put the product at a disadvantage, and will in the long run be disadvantageous to the producers.

While costs of raw materials have to be economic, they need not always be cheap. Chemurgic research may increase the value of a material so that manufacturers will cheerfully pay a premium price. The special cottons described in another chapter, and waxy corn, and weed-free flax straw, are examples. They bring more than the ordinary crops. The whole campaign for new crops is based on the idea that some can be found which will be more profitable to farmers than the old staples which are grown so extensively that their occasional excessive abundance depresses their prices to profitless levels.

Chemurgy can afford no economic illusions. New uses and new crops can be created only on sound economic bases.

II

Some discussion a few pages later will be devoted to statements to the effect that, in some instances, protection by tariff duties or encouragement by incentive payments may be desirable to hasten production of new crops and development of new uses. The habitual slogan thinker will derive from those statements, and from the previous discussion pertaining to domestic production of corps which are now imported from elsewhere, the impression that chemurgy is, after all, nationalistic and therefore invested with evil. This is the place to attempt to clarify, if possible, any conclusions so erroneous.

Chemurgy is definitely an international concept. Science recognizes national boundaries no more than does the sun. When chemurgic research turns up a new fact, that fact is available to all the world.

The Chemurgic Council itself has members in every continent and in two dozen countries, who receive every publication, and the Council is prepared to extend the foreign membership. Leaders in several foreign countries, inspired by the broad concepts of chemurgy and recognizing possible applications under their own flags, have organized chemurgic councils of their own.

A full comprehension of the chemurgic concept reveals an international, human significance which reaches much deeper, however, than the generality of science or the availability of chemurgic information.

Nine-tenths of the human race lives and dies in poverty. Most of the people of the world are "ill-fed, ill-clad and ill-housed." No greater tribute to the accomplishments of the American system of freedom could be paid than to call attention to the fact that two-thirds of the American people are well-fed, well-clad and well-housed. No other people have achieved any comparably universal level of well-being and prosperity.

Poverty prevails among most of the world's people because too little food and too few goods are produced. If all the inequalities of possessions were levelled out as was attempted in Russia, the result would always be the same as it turned out to be there. There still would not be enough to go around. More goods must be produced.

The prevalence of poverty is not the consequence of a general dearth of resources and raw materials. It is essentially the inevitable product of ignorance. When men live where plants grow, but do not know how to convert plant materials into goods for living, their poverty of understanding produces poverty of possessions. They might instead be prosperous if they utilized the resources at their feet.

Only within the century that produced steam and internal combustion engines and electrical power did it become possible to produce enough food to feed the human race moderately well. Only then did the avoidance of disastrous famine become possible. Engines made it feasible to *grow* and to *move* enough food that hereafter famine anywhere will be inexcusable.

The concept of chemurgy is founded upon the existence of new tools for decreasing man's ignorance of the materials and laws of nature and of new tools for utilizing nature's materials by learning to obey her laws. Foremost among these new tools are organic chemistry, plant breeding, and engineering knowledge.

With these modern tools, perhaps enough work can be done in the world to some day produce enough goods to go around. Perhaps enough useful plants can be grown and enough materials made into useful goods, that men everywhere can produce for themselves a degree of comfort and prosperity.

Whoever comprehends the spirit of the chemurgic concept must understand chemurgy's hope that wherever men live and plants grow, progress will be made toward abundance. Here, since we happen to live in the United States, our duty is to concentrate on making the most of the possibilities for this country. At the same time, as members of the human race, the duty is no less to encourage the people of other regions to produce for themselves the things they need for themselves. Whatever knowledge we possess should be offered freely when others wish to follow our examples. The hundred and forty million people of the United States can derive no possible advantage from poverty among any of the world's other two billion human beings. On the contrary, prosperity anywhere can help to make prosperity everywhere.

If a standard of living comparable to that of Americans were now created in Africa and Asia and Europe and in South America, could any doubt exist that American prosperity would be not only safer, but would inevitably rise to much greater heights?

III

The tariff has for more than a century been a political topic. While it ought to be treated purely as an economic subject, that ideal is impracticable. So, despite the political nature of tariff and the severely nonpolitical character of chemurgy, a few words on the tariff as an economic matter have to be included here.

A tariff duty, collected at the point where foreign goods enter a country, is a tax or charge designed to prevent the foreign product from competing unfairly with domestic producers. The importer of clothes pins, for instance, must pay a duty of fifteen cents per gross. The duty on furniture is 25 per cent of its value. The first is a *specific* duty, figured at so much per item. The second is *ad valorem* or according to value. Both types of duty may be levied upon an item. Lead pencils are dutiable at 50 cents a gross plus 15 per cent of their value.

At one time the import duties provided the chief revenue of the United States government. A means of indirect taxation, they kept the federal treasury replenished, with the help of a few other levies, such as internal revenue taxes on liquors and tobacco. Since the cost of government has risen so immensely, income taxes have been instituted and the tariff has become a minor source of federal revenue. Therefore it now is usually considered with reference to effect on production and trade rather than as a source of government income.

When applied as a protective measure, the tariff serves as a sort of floor under prices, although a floor by no means so unyielding as the price-control ceilings established during the war. Opponents of the tariff as an instrument of national policy have always called it not a floor but a wall, or barrier.

Tariff protection could hasten the establishment of several new crops in the United States and in other countries as well. On the free list in the present tariff laws stands an item: "sago, crude, and sago flour"; and another: "tapioca, tapioca flour, and cassava." Sago and tapioca are not grown on America farms, being tropical roots. They would therefore appear to be noncompetitive with any domestic product. If that were true, they ought, like coffee, to remain on the free list. Not well known, incidentally, in the fact that about two-thirds of all imports into the United States, by value, are on the free list, nor that our free list is the largest permitted by any trading nation.

The imports of tapioca, sago and cassava have been very large. In 1937 they reached half a billion pounds. The word flour in connection with them is deceptive. They are starches and they compete with the starch crops American farmers grow. Formerly the tropical starches were able to fit certain requirements better than domestic corn or potato starch and to that extent may have been regarded as noncompetitive. As larger quantities were imported they became more competitive, making their way into uses which domestic starches would have filled, had not the root starches offered to do the jobs more cheaply.

Waxy corn and sweet-potato starch are new. Either can be produced in whatever quantities the American market will demand. Between them they can apparently satisfy any of the special requirements which tapioca starch formerly supplied because cornstarch was not suitable; requirements such as for adhesives on stamps and envelopes.

In the Netherlands Indies, where most of the tropical starches come from, labor is exceedingly cheap. The war-torn Netherlands empire may decide to offer the product of this labor in the American market at whatever price will sell it, always, if necessary, offering it for less than the American producers can afford to accept. If this should occur, waxy corn might have to disappear from American farms. Sweet-potato starch might not find the chance to help displace cotton from the acres presently unprofitable in that crop.

The ideal answer, of course, is that American producers should so increase their efficiency as to be able to compete with producers elsewhere. In the production of such things as motors, this has been done so well that no foreign manufacturers have been able to meet their low costs. To some degree the American rice farmer, using tractor power, airplane seeding and combine-harvesters, has been able to undersell the Oriental rice farmer in Asian markets.

Efficiency, however, has its limits. It can not always be built up to a point where it can compete in opposition to poverty wages of coolie labor, low-priced land, and government-operated cartel selling

What would be the wisest course if tropical starches consistently undersell American-grown waxy corn and sweet-potato starches? Should a tariff duty be applied so as to put some sort of a floor under the American price? Should competion takes its course, even though the result is to eliminate the development of waxy corn and sweet-potato starch in the United States?

The pat comment is that "you can't export unless you import." That rather overlooks the fact that as the second largest importing nation and as the nation with the largest free list, the United States does import quite freely. Then, can industry sell to American farmers unless it buys from them? And, an American farmer might ask whether he is not a somewhat better customer for American manufacturers than are the poverty-stricken Orientals.

No economic question stands by itself. If less corn is grown for starch, more will go into lard, normally a surplus product. If few acres can be planted to sweet potatoes, more acres will have to grow cotton, chronically a surplus crop. When surplus problems become politically pressing, more subsidies will likely be voted. Will the subsidies cost the people more money as taxpayers than cheaper starch will save them as consumers?

Then, what of the effect on the people of the Netherlands Indies? If the United States interposes a tariff duty on their starch products, would not their prosperity suffer? Is it not our duty as an international good neighbor to buy their starch?

We have been buying their starch and admitting it duty free. Have they become prosperous? Or have we merely been exploiting their poorly paid human labor and cooperating in the exploitation of those workers by the imperialist companies who really profit from the trade? Do we tend to keep them fastened to a low-wage, one-product economy which can only exist by perpetuating the poverty of its workers? If the Dutch could no longer export cheap starch, might the way not be opened for the Javanese to produce more of the better food, clothing and shelter, more of the means for better health, education and recreation which doubtless they need for themselves?

It could be that a tariff here on starch importations would actually lead to raising the living standards of exploited peoples elsewhere. They in turn might benefit by protecting some of their own products.

The last word on the tariff and other protective devices has not yet been said. They may be highly desirable to restore balance to world trade, to stimulate production of goods people need in various countries, and to strengthen the incomes of the workers in other lands as well as in the United States.

Starch, in this discussion, has served as a focus of argument. Several of the vegetable oil crops or one of many others might as well have been chosen. A few points for consideration have been raised briefly; the tariff question can not be debated fully in a few hundred words. The reader no doubt holds to his own opinion. As for the author, he will not here belabor the viewpoint but he does believe that the larger interests of the nation, of the people as consumers, as workers, and as taxpayers, will be served by discriminating application of the protective principle where it will help establish some new crops in the agricultural repertoire.

IV

Were this an ideal and orderly world, no government subsidies of any kind for producing goods would be desirable. Since it has become a world where economic forces have been distorted by political forces (ultimately, of course, economic forces are never defeated), men have to consider what courses are practicable. If subsidies are to be granted, the practicable course is to discover how they can be used to assure the most creative effects.

New crops could be encouraged by a system of incentive payments. As a hypothetical instance, let's assume that research had discovered okra seed to be the source of an oil which would supply an important new national need. Farmers naturally would not rush into okra production. Few of them would be well-informed as to the agricultural procedures necessary. Existing mechanical equipment might be imperfectly adapted to okra production, so that further experience would be needed to devise efficient machinery. The crop would not take a firm foothold on farms until growers obtained the information and equipment for its production and were reasonably assured of a profitable market.

Since okra would be a new oil, manufacturers likewise might be hesitant about using it extensively. It might require some modification of customary processes or the installation of different equipment. They could be uncertain as to whether, if they did accept it, future supplies would be forthcoming in adequate quantities.

The situation, then, would be that farmers would hesitate. Uncertain about production costs, they would expect those costs to be higher at first than later on when more experience was available. Manufacturers would be impelled to go slowly because of uncertain supplies and other practical considerations. The okra oil, if it paid farmers at the outset, could be too high in price to interest manufacturers, even though the latter were certain to welcome the product at a lower price.

The incentive payment device could be used in the national interest to bridge over such a situation. The payments would not increase the actual market price. But at so much per pound or bushel produced, they would be expected to cover the unusual risks and costs encountered by the farmer to whom they would be made. With the payment in addition to the market price, he could afford to take some chances. The manufacturer, on the other hand, could proceed to buy the oil for whatever it was worth on the market and would have some assurance that the supplies would be forthcoming year after year. When production methods were eventually stabilized, it should be possible to withdraw the incentive. While politically any kind of government subsidy is supposed to be difficult to withdraw, actual experience has been that in due time, or maybe slightly overdue time, the subsidies disappear. Public opinion will not indefinitely tolerate a conspicuously improper subsidy.

The incentive payment idea is not an entirely new one. It was suggested by this writer in December, 1935, in *The Country Home Magazine*, of which he was then editor, as a replacement for the then already discredited system of acreage restriction payments handled by the Agricultural Adjustment Administration (Triple A), in anticipation of the adverse Supreme Court decision which came a month later. The proposals then published included incentive payments for four types of constructive actions which, it was felt, would help to strengthen our agriculture. They were to:

1. Encourage production of crops for industrial rather than food uses.
2. Encourage production of the agricultural commodities being imported.
3. Encourage rebuilding of fertility by premiums upon soil-improving crops, such as legumes.
4. Encourage planting of erosion-preventing crops.

In a modified form, the idea was adopted for application to the third and fourth purposes listed, and has to that extent become a part of the government's agricultural program. During the war the basic idea of incentive payments was utilized in several instances in the form of a specially guaranteed price, as for hemp, flaxseed and several other products.

So far incentive payments have not been offered for the first two purposes, except for the wartime flax subsidies, unless one also counts the wartime price "floors." Since the obviously sensible approach to the problems of agricultural surpluses is to prevent the creation of surpluses, it would appear that incentives for producing crops of which there are constant national deficiencies would be thoroughly sound.

V

Who should do the research in chemurgy? Whose obligation is it to find new uses for farm-grown raw materials and to seek to set new crops to growing on American acres? And who will do these things?

Answers to these questions are to be found in determining who has been hunting out the facts upon which new crops and new industries can be established. Through the preceding pages of this book many stories of research efforts have been told, but it may be desirable to bring together here a few thoughts on research itself.

Private individuals, industrial corporation laboratories, state universities, independent universities, state experiment stations, state chemurgic commissions, United States government laboratories, and laboratories privately endowed and operated are among the agencies through which chemurgic research has been conducted.

Few will disagree with the assumption that some types of research will not be pursued by other than public agencies and that their pursuit is definitely in the public interest. The benefits of success in a research project with cotton, for instance, or with forest products or in sewage utilization, may be so broad and so difficult to capitalize for a single private interest that only a public agency is likely to undertake the work. Consequently, the appropriation of public funds is in many instances a sound investment of the people's money and is likely to return ample dividends in new wealth and a broader tax base for the future.

Much of the research needed to lay the groundwork for new crops is of this nature. Hardly any private agency, unless purely philanthropic, could be expected to organize expeditions to explore the flora of remote places of the earth in the hope that plant species will be found that might, when tested in American soil, reveal economic usefulness here. Yet all the world's flora ought to be explored for this purpose. When brought into the United States, new plants require a place where they can be given preliminary tests and where they can be multiplied. Then they have to be sent to areas of varying climates and conditions before much can be learned about their adaptability and productivity and to what agricultural sections they may be suited. For this purpose, the existing agricultural experiment stations are ideal, for they are staffed with men trained to precise scientific observation. When a plant has passed the experiment station tests, it may then be offered to individual farmers for final acceptance.

It was to get this done that in 1941 I had a bill written to provide a modest federal appropriation for research on such new crops. It was introduced then and again into each succeeding Congress, until in 1946 its principle was incorporated into the agricultural appropriation act.

Nearly all types of research agencies have taken part in promoting research with soybeans. Government plant explorers had a large hand in introducing new varieties which were tested at state experiment stations and on farms. In the early years farmer enthusiasts carried on many variety experiments. Processors, paint manufacturers and industrial consumers of the oil and meal eventually spent large sums in research on soybean utilizations. A few industrialists, notably Henry Ford, have deliberately sought to find new opportunities to consume farm products in their own manufacturing operations. Their theory has been that by buying more from farmers, more goods can be sold to farmers.

Some of the state universities have discovered that research pays its way in more than one respect. When certain vitamin patents were obtained at the University of Wisconsin, they were assigned to the Wisconsin Alumni Research Foundation. This foundation in turn licensed manufacturers who wished to use the patents. The manufacturers pay a royalty to the foundation. The several million dollars which have thus been returned have been used to finance further research and to develop other activities in the university. Purdue, Ohio State and others benefit from similar arrangements by which facts pay for finding more facts.

Awareness of undiscovered frontiers is increasing. A notable Kansas City development, lately unfolded, indicates the appreciation of the extent of under-utilized resources which are still underfoot. J. C. Nichols, a highly successful real estate developer whose business vision has contributed hugely to the beauty and excellence of his city, conceived the idea of creating there a Midwest Research Institute. Starting with a very substantial contribution of his own, Nichols induced a group of wealthy friends to join in subscribing a $500,000 fund. After study of methods and consultation with officials of the Mellon Institute in Pittsburgh, the Battelle Memorial Institute in Columbus and other outstanding research centers, Nichols and his associates employed a competent research director and opened up. Within hardly more than a year the place was crowded with projects which middle west companies wanted studied and were anxious to pay for. The institute will center on the agricultural and mineral opportunities of the states around Kansas City.

So extensive and numerous are the research challenges in the fields of chemurgy that years of research can not exhaust the opportunities. Each new bit of knowledge is likely to create new questions and open upon doors to new studies.

Room is ample for any individual or agency with energy, ideas and means.

Who should do research in chemurgy? Whoever can get it done!

CHAPTER XXIII

A Force for Peace

I

ALL over the world human beings long for plenty and for peace in which to enjoy it. Plenty has never been the lot of more than a tiny fraction of all those who have lived through all the unnumbered generations of mankind's existence on earth. The history of the centuries shows nothing more clearly than that peace always has been an exceedingly brittle and elusive jewel, easily broken and easily lost.

War is by no means a phenomenon of mere political behavior. While the overt acts of aggression may be initiated by the personal desires of national leaders for their own political aggrandizement, and while a people may be propagandized into patriotic support for aggression, the basic causes of war are economic. Before aggression arises there is always a widespread national conviction of want or a national psychosis of envy.

Yet, although aggressive war has its roots in economic disparities, statesmen give far more thought to political than to economic preventives. Symptoms receive their study while the causes tend to be ignored.

Here in the midst of the twentieth century statesmen are repeating the incantations which were ancient when alchemy was the nearest thing to chemistry. They are trying to fashion peace with formulas that are the same old witch-brews in which their medieval predecessors in statesmanship futilely put their faiths. Their tools are alliances and balances of power, bluffs and lies, leagues and treaties, coalitions and alignments, threats and compromises, notes and ultimatums, gold lace and striped pants. All these have been tried for five hundred years and all have failed again and again, except to generate new wars. Nothing in the formula is new except the striped pants and they, already, have an equally consistent record of failure.

The very nature of the politicians who become the statesmen is to be ill-educated in economic matters. They are not much interested in the production of goods—seldom do they really comprehend the business. If they were interested by nature, perhaps they would not have devoted their talents to politics, but instead would have become scientists or farmers or industrialists. Unfortunately or not, those with talents for production and inherent understanding of productive processes seldom find time to give to public affairs the full weight of their abilities.

Since statesmen have tried every other imaginable means to prevent wars, and have repeatedly failed, would it not make sense now for them to concentrate on attempting to reduce the basic cause of war, which is want of food and goods? Even if that course also failed, everyone, everywhere, would still be better off; and, for that matter, better equipped to make more war! No one loses when production is increased.

The new scientific and practical knowledge of the more advanced peoples is adequate, if universally applied, to wipe hunger and want from the face of the earth. Man has the power, the machines, the knowledge of materials and methods, to produce plenty for all this world's two billion human bodies. The soil and the seas, the mines and the forests, contain the raw material resources to yield a world-wide abundance.

True, minerals and sunshine are unequally distributed. Even so, wherever masses of population are found, plant life is either abundantly producible or fairly accessible. New forms of transportation improve the mobility of plant materials. Chemurgy, dealing with these ever-renewable and inexhaustible raw materials, opens new routes to universal abundance.

Is it possible that on this seemingly narrow concept of new uses for crops and new crops to be derived from the earth's plant life, a new basis for peace among men might be built?

The suggestion will bear examination. Perhaps one should approach it first from the viewpoint of one seeking peace and safety for his own country.

II

Americans almost universally agree that the United States must maintain armed strength in the present chaotic world. No one doubts that the American influence for a future peaceful world can best be exerted if backed by capacity to wield force if necessary. Until a workable world scheme appears, the air forces, the army and the navy should be well maintained and the lights kept burning in the laboratories of destruction.

No lesson of the war was more sharply driven home than that the national defense reaches far behind the armed forces. The industrial production of the nation was its most powerful weapon. That production, in turn, depends upon ample supplies of the raw materials out of which war materiel is manufactured.

The United States was caught short on rubber. While this shortage was the most conspicuous, it was only one of countless failures to prepare on the economic front. The United States was short of scores of other commodities, and many of the shortages were exceedingly serious. Had the war continued longer, some of them would have been felt keenly in both military and civilian respects. Behind the scenes, strenuous efforts had to be made at huge cost to overcome shortages or to prevent the disasters that could have occurred had the war been protracted, had the submarine attacks continued longer to be successful, or had less shipping been constructed.

Millions upon millions had to be spent because the United States was short of hemp, flaxseed, kapok, castor oil, tung oil and scores of other agricultural items. The list was made up largely of the precise products which chemurgy had steadily insisted should be developed not only to occupy acres devoted uselessly and troublesomely to unneeded surplus crops, but because they might some day be vital to the national defense.

From its very beginning, chemurgy has stood for national strength and economic preparedness. Evidence of this fact is contained in a statement made a few weeks after the National Farm Chemurgic Council was first organized.

Secretary Wallace had appointed a committee within the Department of Agriculture to review the department's research program and to offer suggestions for its improvement. M. L. Wilson, then Undersecretary of Agriculture, was chairman of the committee. Upon Mr. Wilson's invitation, in July 1935 I presented a comprehensive outline of proposed research along chemurgic directions. The statement was submitted in the form of a brief prepared in advance. The brief opened with the following paragraphs:

> The national defense must always be a foremost consideration of statesmen. To the end that the peace and safety of the United States shall be assured, we take for granted the necessity for maintenance of an army with sufficient subsidiary means for military preparation, of a navy prepared to defend our shores and ships—both with their various branches for air, land and water, and their supporting agencies.
>
> Preparation for provision of adequate supplies of all kinds for these fighting agencies, from our own national sources within our own national borders, is looked upon as an axiomatic necessity of

> national defense. Such supplies include not only munitions, food, clothing, medical requirements, and transport for the fighting forces, but all commodities necessary for the support and morale of the non-combatant population of the country.
>
> From the standpoint of national defense, the clear objective of research should be to make provision for the production, at some cost, from some domestic source, of every item that it is anticipated may ever be required for the use of our defensive forces; and, further, of every item of domestic need that might be shut off by the incidence of foreign wars in which this country may not be engaged.
>
> Department of Agriculture research projects which clearly contribute to these ends should, therefore, be worthy of consideration by the Congress.

It is hardly necessary to remark that had this statement been accepted as a policy in the Department of Agriculture and been followed during the intervening six years, the state of the nation's economic preparedness on December 7, 1941, could have been far more creditable, and the war cost far less.

In the light of the current apparent determination to maintain a higher degree of military preparedness than ever before, the policy would now seem to be indispensable.

A fact noted earlier in these pages may be repeated here. Farm-grown materials entered into the manufacture of every warship, airplane, cannon and tank built for the nation's armed forces, and into the fuel and the ammunition that were used. Chemurgy is an intimate factor in making the tools of defense.

But chemurgy's greatest opportunity is to help create the tools of peace around the world!

III

Rubber can never again be the monopoly of any two or three nations. Synthetic rubber and new sources of natural rubber assure that.

Motor fuel and aviation fuel need no longer be exclusive monopolies for any few nations. Those who do not have petroleum or for whom oil is too expensive, can obtain fuels from their carbohydrate plant materials.

Neither cotton nor silk can be of major importance as monopolies in a world that can make rayon, nylon and other synthetic fibers.

Iron and structural metals begin to diminish in importance when techniques are known that enable wood and plastic materials to perform their formerly exclusive functions.

Examples might be extended to a wearisome list, and all would add their weight of confirmation to a tremendously important chemurgic fact.

This fact is that the interchangeability of materials and the availability of more than one kind of material to perform a given basic function have vastly increased the potential self-sufficiency of all nations. Having done that, they have also vastly elevated the potential standard of living for the peoples of all nations.

Take only a smattering of facts about standards of living in Asia and in Africa. Take only the few generally known facts about the soil, climate and natural resources of those continents. Who can doubt that the installation of modern power, modern machines, some modern transportation and modern agricultural skills could easily double the pitifully low standards of living on those populous continents? Double Asiatic and African living standards, by increased production of food and of goods needed in those great areas, and the effective demands there for the more advanced manufactured goods of Europe might well be doubled. The prosperity of three-fourths, if not of all the world, would rise markedly. Given evidence of a comfortable rising trend in living standards, the disturbed and unhappy peoples of the Old World poison spots would begin to settle into a state of contented progress. The rabble-rousing maniacs of the future would find far less welcome for their hoarse hatreds.

Is all this visionary?

Not so visionary as it is to put all human faith in the outworn abracadabra of traditional statesmanship! Mankind has ample evidence by now that the political formulas are formulas for failure.

In North America it has worked. The American standard of living speaks for itself. The Canadian standard, rising steadily alongside ours, has been a factor in the long peace and unfortified border, undoubtedly quite as effective as the natural and mutual ties between these two friendly nations. The people of each have never doubted their ability to produce wealth more easily and cheaply than either could gain an improved status by looting the other.

There is room for tremendous doubt over the ability of statesmen to create durable peace by their easily broken pacts and papers.

There is no doubt that human want could be enormously reduced by a universal concentration of effort toward the production of food and goods.

There can be little doubt that the relief of want and the consequent infusion of hope into the souls of men everywhere would fertilize the soil of peace.

IV

What stands in the way? If the whole human race can lift itself from want, why does it not forthwith proceed to do so?

A thousand reasons can be advanced by the no-doubt-butters, and most of them may be sound reasons. Ignorance, imperialism, lack of capital—anyone can write down a formidable list of difficult obstacles. But no matter what the obstacles may be, common sense can prove that the achievement of plenty is no impossibility.

Americans have done it. Their resources were not superior. To say that here a superior people were assembled is to flatter our native vanity but the assertion is neither provable nor polite.

The basic explanation and essentially the only one is that here individual freedom gave rise to economic leadership that saw opportunities in production. Government was the servant and never the master during the century and a half of American rise. Maybe freedom is a prerequisite to abundant production. If so, then the areas of freedom must find ways to expand.

With freedom or without it, any nation's production can be enlarged if the national leadership will concern itself with production. That seems to be demonstrated in Russia. Apparently it was also shown in Nazi Germany, although their production, the people being without freedom, was channeled to war.

I have something deeper than a mere notion that if the thinking people of America and of a few other countries fully grasped the potentials of world-wide productivity and then raised their voices at home and abroad to extend their understanding, they might in no great time find themselves achieving a doubly great work—the humanitarian accomplishment of helping the less fortunate of the earth to help themselves, and the even nobler task of charting thereby a road that truly can lead to durable peace.

The chemurgic concept points out abundant new resources. The chemurgic sciences have shown how these new resources, the celluloses, oils, proteins and compounds of plant life, all inexhaustible and ever-renewable, can be converted into good things for humans to use. Plant-life resources are far more generously distributed over the geography of the earth than is mineral wealth. Nations with soil and rain and sun as well as nations with iron and gold and coal can become rich.

Isn't it time, then, that the rulers of men, the leaders of nations, woke up to the facts of modern productive science?

Isn't it time for leaders to arise who fully comprehend that far more wealth can be produced than can ever be stolen?

Isn't it time for men to abandon the ancient and evil predatory philosophy? Should not modern leadership build its right to lead on the productive philosophy, on the idea that it is far more profitable to create new wealth out of the soil than to depend on conquest and loot, or even on exploitation of ignorant labor?

Growing things and making things, pays better than taking things!

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